VOLUME ONE

HYDROLOGIC INVESTIGATIONS

PEACE-ATHABASCA DELTA PROJECT

[Canada. Dept. of the Environment]

The Peace-Athabasca Delta Project

[General publications]

[G-1] TECHNICAL APPENDICES
VOLUME 1, 1973

HYDROLOGIC INVESTIGATIONS

Prepared by
The Peace-Athabasca Delta Project Group
Canada Alberta Saskatchewan

A CO-OPERATIVE INTERGOVERNMENTAL STUDY ESTABLISHED BY THE ENVIRONMENTAL MINISTERS OF CANADA, ALBERTA AND SASKATCHEWAN

HON. W. J. YURKO for Alberta	HON. JACK DAVIS for Canada	HON. N. E. BYERS for Saskatchewan

Technical Report Appendix

Volume 1

Forward

In January, 1971, the Governments of Canada, Alberta and Saskatchewan established a cooperative interdisciplinary study group to investigate and report on the cause and effects of low water levels in Lake Athabasca. The focus of the investigations was directed towards determining the effects of low levels on the Peace-Athabasca Delta located at the West end of Lake Athabasca and on the people of the area.

The information contained in this volume covers the hydrologic studies carried out under the Peace-Athabasca Delta Project. The complete report consists of:

Summary Report, 1972
Technical Report
Volume 1, Hydrologic Investigations
Volume 2, Ecological Investigations
Volume 3, Support Studies

The technical report provides a detailed analysis of the cause and effect of the lower water levels and recommendations for remedial action. Volume 1, 2 and 3 contain detailed reports on the hydrologic, ecological and supporting investigations. The Summary Report, based on the Tecnnical Report but presented in nontechnical language for public distribution, briefly describes the various technical and management aspects of the Project.

The hydrologic investigations were coordinated by J.R. Card who was seconded to the Project by Alberta Environment. Technical advice in structuring the studies was provided by members of the Technical Advisory

Committee. These members represented the following organizations: Environment Canada (Water Planning and Management Branch) (Inland Waters Branch), Canada Department of Public Works, Ministry of Transport, and Saskatchewan Department of Environment. Other agencies involved in the technical input to the various programmes were Research Council of Alberta, University of Alberta (Civil Engineering Department), Canadian Armed Forces, and Northern Transportation Company Limited. The Peace-Athabasca Delta Project provided logistic and office support for the hydrologic investigations.

This volume of appendices related to hydrologic investigations begins with four sections (sections A to D) which describe the hydrologic and hydraulic conditions which exist in the Delta. Section E examines the water levels in the Delta which would result if no corrective measures are taken, and Section F outlines various courses of action which have been considered for the control of water levels. The remaining sections cover a variety of subjects related to the hydrologic and engineering aspects of the Project which ranged from investigations into the use of an ice dam, to navigation, to water quality, to geology and to ground water.

The contribution of all individuals and agencies who participated in the preparation of these reports is gratefully acknowledged.

The Peace-Athabasca Project Group adopted the policy that the participating agencies were responsible for the individual reports prepared for the project. The views and opinions expressed in the appendices are therefore not necessarily those of the Project Group.

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B Factors Influencing Water Levels. J. R. Card, Hydrology Branch, Alberta Department of the Environment, Edmonton, 1972.

C Mathematical Simulation of the System. Gepac, Stanley & Associates Ltd., and Hydrology Branch, Alberta Department of the Environment, Edmonton, 1972.

D Peace River Flows and Their Effect. J. R. Card, Hydrology Branch, Alberta Department of the Environment, Edmonton, 1972.

E Future Water Levels. Gepac, Stanley & Associates Ltd., and J. R. Card, Hydrology Branch, Alberta Department of the Environment, Edmonton, 1972.

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O	Water Quality. S. Reeder, and P. Fee, Western Region, Water Quality Branch, Environment Canada, Calgary, 1972.

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P An Empirical Reconstruction of Water Levels for Lake Athabasca (1810-1967) by Analysis of Tree Rings. C. W. Stockton, and H. C. Fritts, University of Arizona, Tucson, Arizona, 1971.

Q Construction Site Investigations. R.M. Hardy & Associates Ltd., Edmonton, 1971.

SECTION A

SECTION A

HISTORY OF WATER LEVELS

R. M. Bennett

Water Survey of Canada

Calgary

J. R. Card

Hydrology Branch

Alberta Environment

Edmonton

1972

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HISTORY OF WATER LEVELS

LAKE ATHABASCA

Water levels on Lake Athabasca have been recorded at Fort Chipewyan for varying time periods since 1930, at Goldfields from 1942 to 1956, and at Crackingstone Point (Gunnar Mines) since 1956. These records were referenced to several different elevation datums, making it impossible to use the entire record without extensive adjustments. Thus, Water Survey of Canada undertook a complete review and co-ordination of the historical stage records and elevations to ensure consistency and utility of the data for the period of record.

Two major requirements were that (1) daily water levels at all three lake stations be checked for consistency of record, and (2) missing records at one station be estimated from lake levels at the other stations. Short periods of missing records were estimated manually. Complete documentation of the review procedures and the compilation of the final results are contained in "Lake Athabasca Water Levels 1930 - 1970" by R. M. Bennett published by Water Survey of Canada, Environment Canada (formerly Dept. of Energy, Mines and Resources) at Calgary in 1970. The publication also contains descriptive statistics of the data which are not duplicated in this section.

In Appendix A-1 of this section the levels of Lake Athabasca are tabulated for the period 1930 to 1972.

Lake Claire and Mamawi Lake

Created out of the former west end of Lake Athabasca by the merging of the Peace Delta and the Athabasca Delta, these two lakes are now the dominating physical features of the detailed study area. Both lakes are shallow basins of sedimentary materials. Lake Claire is seldom more than 10 feet deep even at high water levels, and in March, 1971 was found to be only 5 feet deep

was also found to be completely frozen in March 1971, with a maximum ice depth of only 1.5 feet. The elevation-volume and the elevation-area relationships of these lakes are given in Figure 1. The shorelines of these lakes are not sharply delineated physical features of the landscape and are more readily delineated by vegetation characteristics. Using vegetation as the criterion, the shoreline of Lake Claire is estimated to be at elevation 689 feet, and that of Mamawi Lake at 688 feet. Extrapolation of the volume of area curves above these elevations is not advisable due to a lack of topographic data.

Lakes Claire and Mamawi have a watershed of approximately 8,100 square miles which provide direct runoff. The Birch River with headwaters in the Birch Mountains southwest of Lake Claire is the largest of the tributaries, draining some 4,900 square miles. The McIvor River is the only other tributary of significance. It also originates in the Birch Mountains and drains an area of 600 square miles. The remainder of the lakes' watershed is comprised of poorly drained lowland.

Only the flow of the Birch River has been consistently recorded since 1968. Miscellaneous measurements were made on the McIvor River in 1971 but these are not sufficient to determine the total flow pattern of that river. The mean monthly flows of the Birch River are shown graphically in Figure 2. There is a large variability from month to month and even from year to year. In the five-year period of record a minimum annual discharge of 330,000 acre-feet in 1970 may be compared to the maximum in 1968 of 1,160,000 acre-feet.

Water may also be added to these lakes from Lake Athabasca and the Quatre Fourches. When the water level in Mamawi is lower than that in Quatre Fourches, water flows westward into Mamawi. In a similar manner a westward flow of water into Lake Claire will occur if the level of Mamawi Lake is higher. The measured flow into Mamawi Lake from Quatre Fourches ranged from zero to 10,700 cubic feet per second. This maximum measured inflow

was likely exceeded in the spring of 1971 during ice breakup when metering was impossible.

Floods which top the channel banks of the Peace River and the Embarras River provide water to both Claire and Mamawi Lakes. A flood on the Peace River which raises the river levels sufficiently high to overtop the south bank at Sweetgrass Landing will cause a southward flow of water in the Claire River and an overland sheet flow. Similarly, when the Embarras River tops its banks there will be overland flow westward toward Lake Claire and also some flow created in Gull River. Mamawi Creek, flowing northward into Mamawi Lake, will also receive water from the flooding Embarras River and this will augment the waters of that lake.

Before water from the Peace River will overflow its south bank at Sweetgrass Landing the river must reach an elevation of 715 feet, which is equivalent to a discharge of approximately 500,000 cubic feet per second. An ice jam could raise river levels to 715 feet even though the discharge might be less than 500,000 cubic feet per second. Similarly, the Embarras River must attain an elevation of 708 feet to overtop its banks, and this would require a flow of 28,000 cubic feet per second or the occurrence of an ice jam.

Outflow from Lakes Claire and Mamawi is by way of the channel joining Mamawi Lake with Quatre Fourches. The rate of flow in this channel is determined by the difference in water levels between Mamawi Lake and Quatre Fourches. Another very small channel called Grochier Creek will carry water out of Mamawi Lake when the lake levels are higher than 689 feet. Lake Claire is joined to Mamawi Lake by the Prairie River and outflow from Lake Claire occurs when its level is higher than that of Mamawi. Conversely, as mentioned above, a higher level of Mamawi creates an inflow to Lake Claire which can be considered an outflow from Mamawi Lake.

Observations of outflow in Prairie River and at the outlet of Mamawi Lake produced values from zero flow up to 2900 cubic feet per second in Prairie

River and as much as 6,000 cubic feet per second out of Mamawi Lake. The flow of water into Lake Claire via the Prairie River was occasionally measured in 1971 and 1972 and ranged from zero flow to a maximum measured westward flow of 3,400 cubic feet per second. Based upon very tentative measurements and observations it appears that Lake Claire would not be capable of draining lower than elevation 685 and Mamawi lower than elevation 684. The winters of 1971 and 1972 saw both lakes recede to these elevations and then freeze with no further outflow. However, since the outflow channels are located in silt materials they may not be stable enough to maintain the foregoing condition if unnaturally low water levels are experienced near Quatre Fourches for several years.

Levels of both lakes have been observed for the years 1960 and 1968-72 and are illustrated in Figures 3 and 4. Mamawi Lake levels are similar to those of Lake Athabasca. Lake Claire levels do not reflect the same fluctuations as Athabasca but do show a dependence on Lake Athabasca due to its influence on the outflow from Lake Claire.

Baril Lake

Baril Lake is a very shallow basin within the inactive Peace Delta at the northeast side of Lake Claire. It has an area of 27 square miles but is only 4 or 5 feet deep even at high water levels. The established shoreline as delineated by the present vegetation is at elevation 688.5. Below this level there is virtually no hydraulic connection between Baril and the adjoining Lakes Claire and Mamawi. However, when water levels in Baril Lake exceed this elevation as they did in the spring of 1972, then the water spreads out over the shoreline and joins with the waters of Claire and Mamawi.

Inflow to Baril Lake can be from the Peace River by way of the Baril River during high stages on the Peace and by way of overland flooding from Lake Claire or Mamawi Lake. Flow in the Baril River is restricted somewhat at

the Peace River end by a winter road crossing.

Water leaves Baril Lake via the Baril River when the Peace River is lower than the lake. This flow relationship is illustrated in Figure 5. Since this relationship was derived from preliminary survey information it must be considered as tentative, but it does present some indication of the flow possibilities.

The levels of Baril Lake as observed during 1971 are recorded in Figure 6. Higher 1972 levels resulted from ice jams on the Peace River in the spring and then high Peace River flows in June and July.

Richardson Lake

Richardson Lake, located in the extreme south of the Athabasca River Delta, was earlier recognized as a key spawning area for commercial walleye. The fact that the lake's role as a spawning ground was thought to be jeopardized by low water levels gave added impetus to the study of its hydrologic characteristics.

This lake is also very shallow, being in the order of 4 feet deep. It has a surface area of 28 square miles. The outlet of the lake, known locally as Jackfish Creek, controls the level of the lake when the lake is low. This outlet channel is highly unstable because it is formed of fine sands and silts. It is an area of erosion during low water levels in the Athabasca River and an area of deposition of sediment when the river is high and Jackfish Creek is flowing into Richardson Lake. The creek has created its own small deltaic formation at the lake, which results in several shallow bars in that location.

Coincident with this small delta is the mouth of the Maybelle River which flows into the lake from the south. This river drains an area of 630 square miles and is the only significant tributary. Most observations

indicate that the Maybelle River waters do not mix with the waters of Richardson Lake but leave almost directly via Jackfish Creek if the flow of the creek is away from the lake. However, an inflow condition in the creek results in the Maybelle River waters being held in the lake. During periods of flood flows or ice jams on the Athabasca River, water from the river may spill over the banks and enter Richardson Lake from the north and west sides. This occurred in both 1971 and 1972.

Observed lake levels have been recorded and are illustrated in Figure 7. Indications are that the lake levels are more dependent upon Athabasca River flow than upon the levels of Lake Athabasca. The river surface profiles illustrated in Figure 8 show that Richardson Lake does experience some of the backwater effect from Lake Athabasca, but the range of observations was too limited to assess the extent of this effect.

A critical factor in determining Richardson Lake levels is the flow in Jackfish Creek. The range of measured flows is illustrated in Table 1. One of the factors controlling flow in the creek is the elevation of the sand bars at the outlet of the lake. On the basis of surveys in the winter of 1971, the outlet control is estimated to be at elevation 686. However, as mentioned previously the elevation is subject to change depending upon the amount of sedimentation or erosion taking place.

Since walleye start their spawning migration into Richardson Lake just before spring breakup, it is important that water under the ice at the lake outlet be deep enough to allow them access to the main body of the lake. Further observations are required to determine the optimum lake level to ensure that the fish can move into the lake.

Other Lakes

It is the smaller lakes and basins of the Delta which are the most significant as far as the wildlife populations are concerned. Observations

have been made in many of the hundreds of small basins with a view to determining their hydrologic characteristics and the relationships of their water levels to the larger adjacent lakes.

Three types of small basins have been identified with respect to the way in which their water levels fluctuate. The first of these are basins whose water levels rise and recede in close coordination with a nearby large lake or river channel. These basins have an unrestricted hydraulic connection with the nearby lake or river which permits the unhindered inflow and outflow of water in accordance with the relative difference between levels in the two bodies of water.

The second type of basin has a restricted hydraulic connection with a nearby lake or river channel so that the water level in the basin responds to the fluctuations in the nearby source on a slower scale, or under certain conditions, not at all. When both the basin and the source waters are at a high level the fluctuations of water levels may be ver closely related. However, when both basin and source recede and are at very low levels in relation to the topography of the connecting channel then the basin level may be virtually independent on the fluctuations within the nearby lake or river channel.

The third type is a true perched basin or lake which has no obvious inlet or outlet channel and which must be filled by overland flooding from some source such as an adjacent lake or river. Water levels in the perched basin fluctuate independently of the source except when filled by flood waters. These basins are extremely sensitive to precipitation and evapotranspiration when they are not filled by flooding. The water levels in such basins recede almost entirely due to evapotranspiration.

Staff-type water gauges were established in 24 basins throughout the Peace-Athabasca Delta in May 1971, and weekly readings of these gauges were made until October (Figure 9). The purpose of the gauges was to determine the

rate and magnitude of water losses from isolated basins and to observe the extent of the effects of flooding of the major rivers.

The graphs of Figure 10 reveal the water level characteristics of three types of basins with respect to the 1971 Delta water levels: 1. completely isolated basins (no. 18, 241, 391, 400, 271, 274, 278, 226, 244, 394, 360, 306, 46) 2. restricted-drainage basins (no. 7, 199, 351, 188, 159, 116, 123, 55, 45) 3. open-drainage basins (no. 160). One basin, no. 307, cannot be described in these terms.

It had been thought that the melting of an impervious frost layer below some of the basins might result in a sudden water level decline during mid-summer. There was no evidence of such an occurrence in the 24 basins observed, unless it was masked by the inflow and outflow of flood waters.

Table 2 provides a summary of water level changes in the 24 basins investigated. The "balance" column of the table indicates that the net loss or gain in restricted basins depends on the relationship of the inlet/outlet to the existing water level and on the height and duration of flooding.

The average rate of loss of water for the 13 isolated basins in the sample was 0.07 feet per week, including the effect of precipitation and local runoff. This loss rate is applicable to the Delta for the period May 26, to October 24, 1971, indicating that the average total water level decline from isolated basins was 1.52 feet. Local spring runoff adding 1.52 feet of water to the basins would be required to maintain a regime similar to 1971, under which, however, several basins were dry by midsummer. Without such replenishment, a 3-foot deep pond theoretically could be dry within two years.

TABLE 1 Flows in Jackfish Creek

Date	Discharge	Direction of Flow
June 3, 1971	352 cfs	out of the lake
June 16, 1971	7,320 cfs	into the lake
July 8, 1971	2,450 cfs	into the lake
July 20, 1971	13,400 cfs	out of the lake
August 5, 1971	4,050 cfs	out of the lake
August 19, 1971	1,240 cfs	out of the lake
September 1, 1971	nil	no flow
June 2, 1972	2,510 cfs	out of the lake
June 22, 1972	5,020 cfs	out of the lake
July 5, 1972	3,850 cfs	out of the lake
July 18, 1972	2,250 cfs	out of the lake
August 24, 1972	1,680 cfs	out of the lake

TABLE 2 Water Level Changes on 24 Basins in the Peace-Athabasca Delta, May 26 to October 24, 1971. (all values in feet)

Basin Type	Number	Total Losses	Total Gains	Period (Weeks)	Total Loss Including Precipi-tation	Loss Per Week
Isolated	18	1.08	0.14	21.7	1.22	0.06
	241	0.71	0.19	18.9	0.90	0.05
	391	2.26	0.98	21.7	3.24	0.15
	400	1.13	0.00	11.1	1.13	0.10
	271	0.47	0.00	7.1	0.47	0.07
	274	1.16	0.06	20.3	1.22	0.06
	278	1.02	0.05	21.7	1.07	0.05
	226	0.21	0.00	3.4	0.21	0.06
	244	0.53	0.00	9.1	0.53	0.06
	394	0.67	0.00	10.3	0.67	0.07
	360	1.53	0.16	21.7	1.69	0.08
	306	0.93	0.17	19.4	1.10	0.06
	46	0.73	0.14	9.1	0.87	0.10
				Balance		
Restricted	7	2.03	1.70	−0.33		
	199	1.38	2.60	+1.22		
	351	1.04	0.80	−0.24		
	188	0.99	0.85	−0.14		
	159	—	—	—		
	116	2.55	2.41	−0.14		
	55	2.45	2.30	−0.15		
	45	1.15	1.27	+0.12		
	123	—	—	—		
Open	160	—	—	—		
Unclassified	307	1.25	1.16	−0.09		

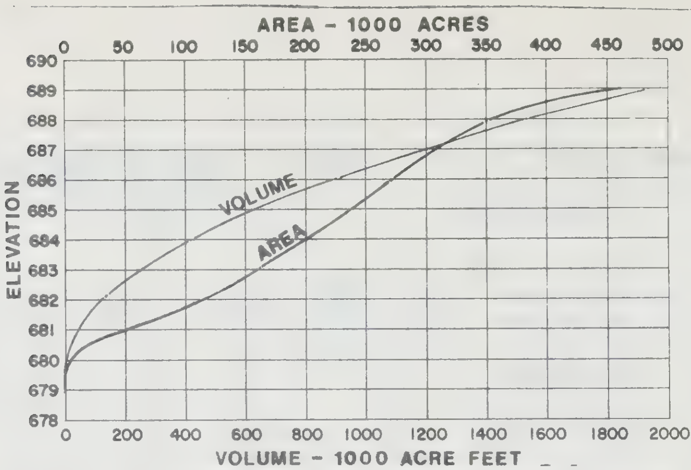


FIGURE 1 Volume, Area, and Water-Level Relation of Lakes Claire and Mamawi

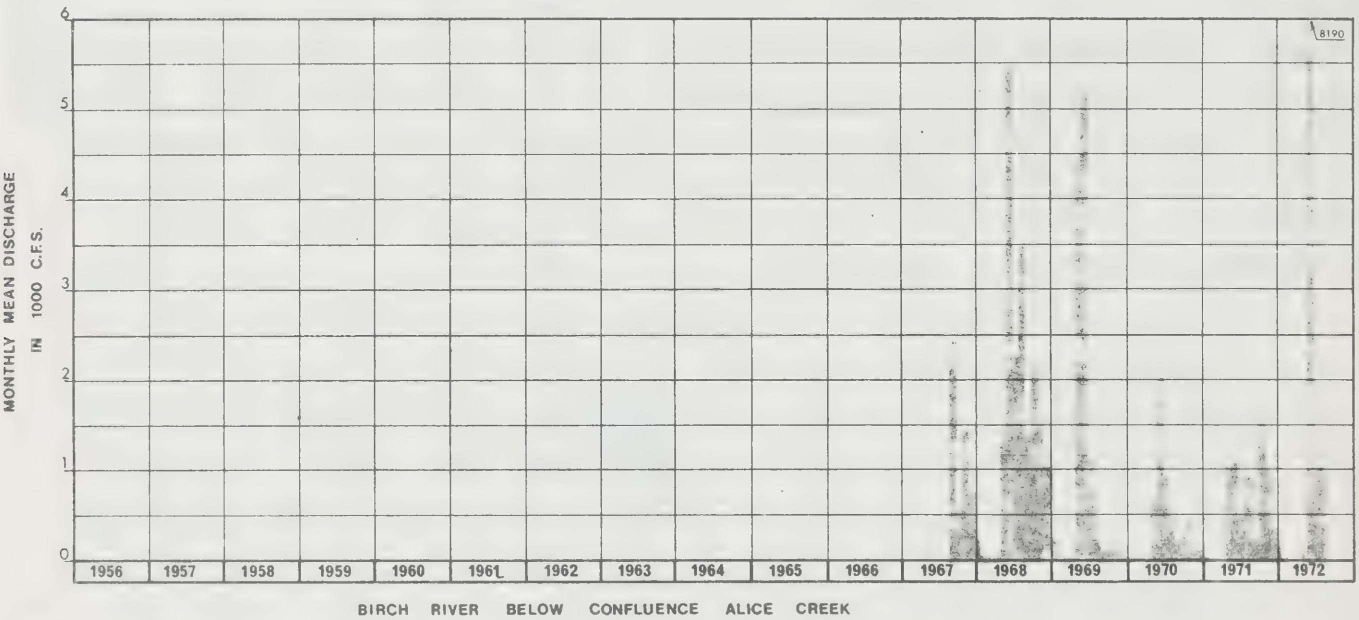


FIGURE 2 Recorded Flow of the Birch River

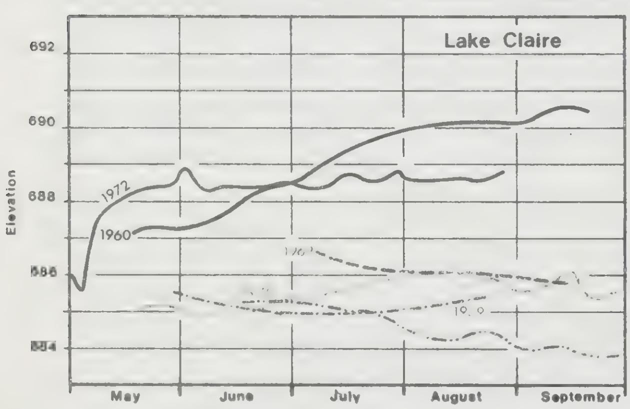


FIGURE 3 Recorded Water Levels, Lake Claire

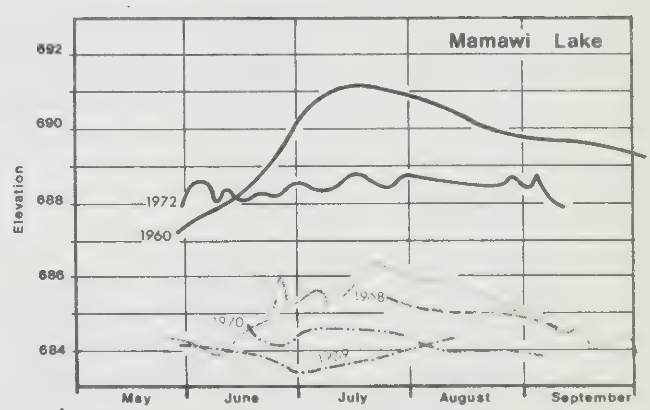


FIGURE 4 Recorded Water Levels, Lake Mamawi

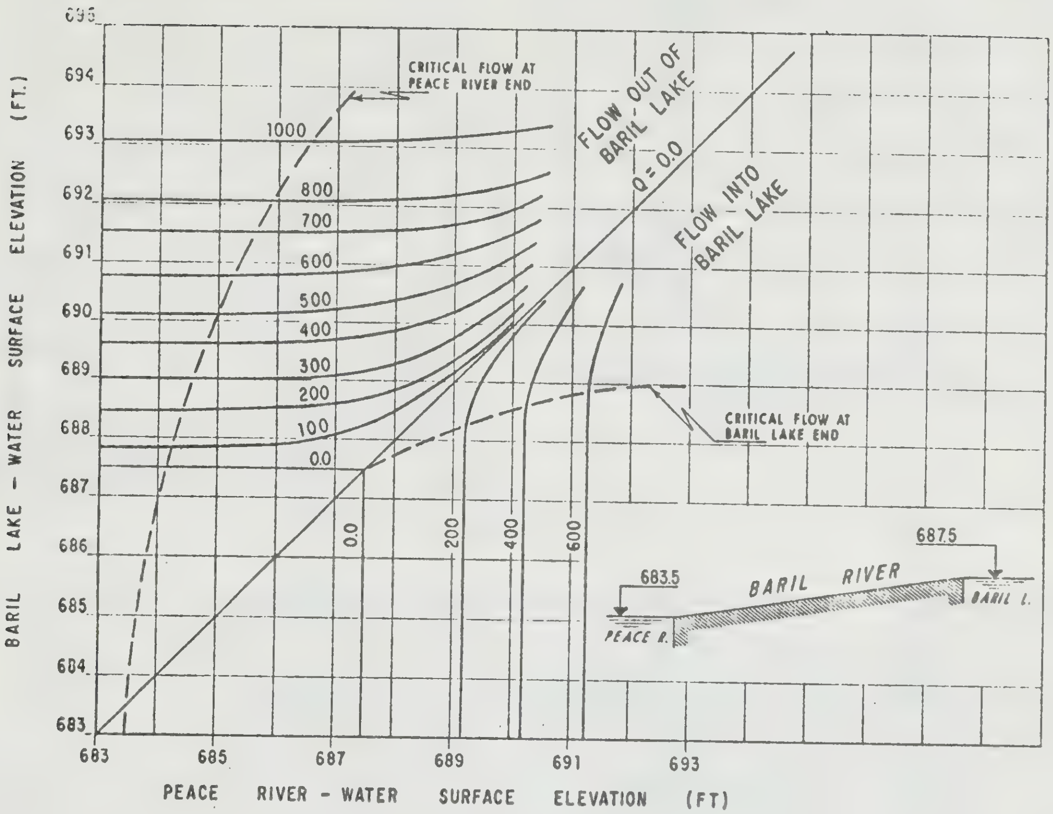


FIG. 5 - Baril River discharge as a function of Baril Lake and Peace River elevations.

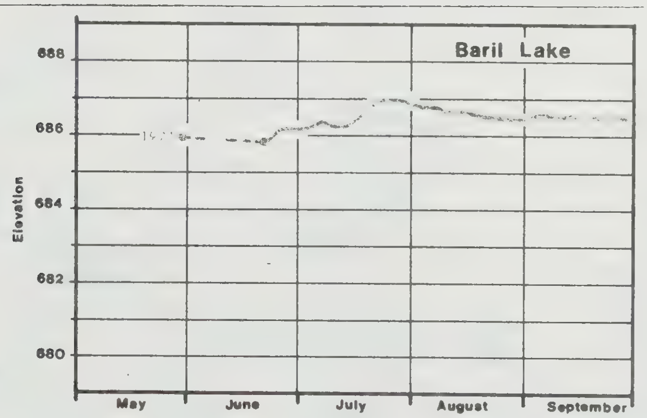


FIGURE 6 Recorded Lake Levels, Baril Lake

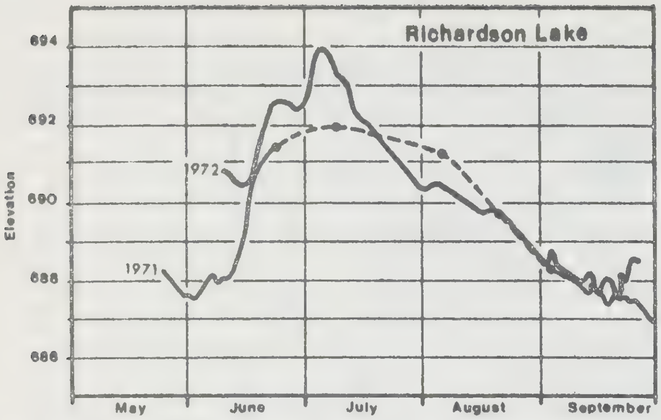


FIGURE 7 Recorded Water Levels, Richardson Lake

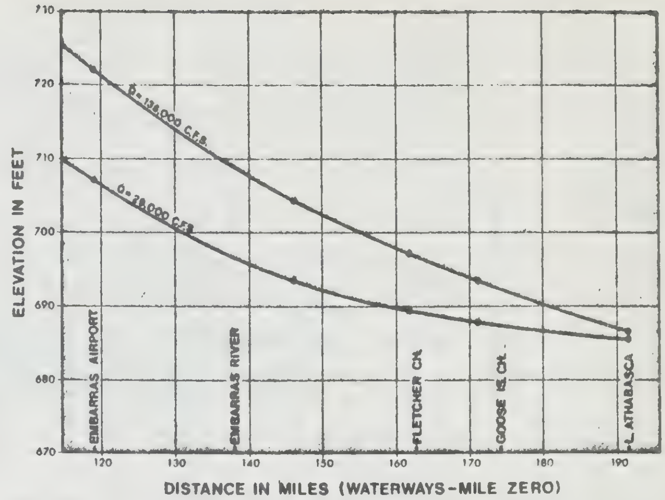


FIGURE 8 Profiles of the Athabasca River Surface near its mouth

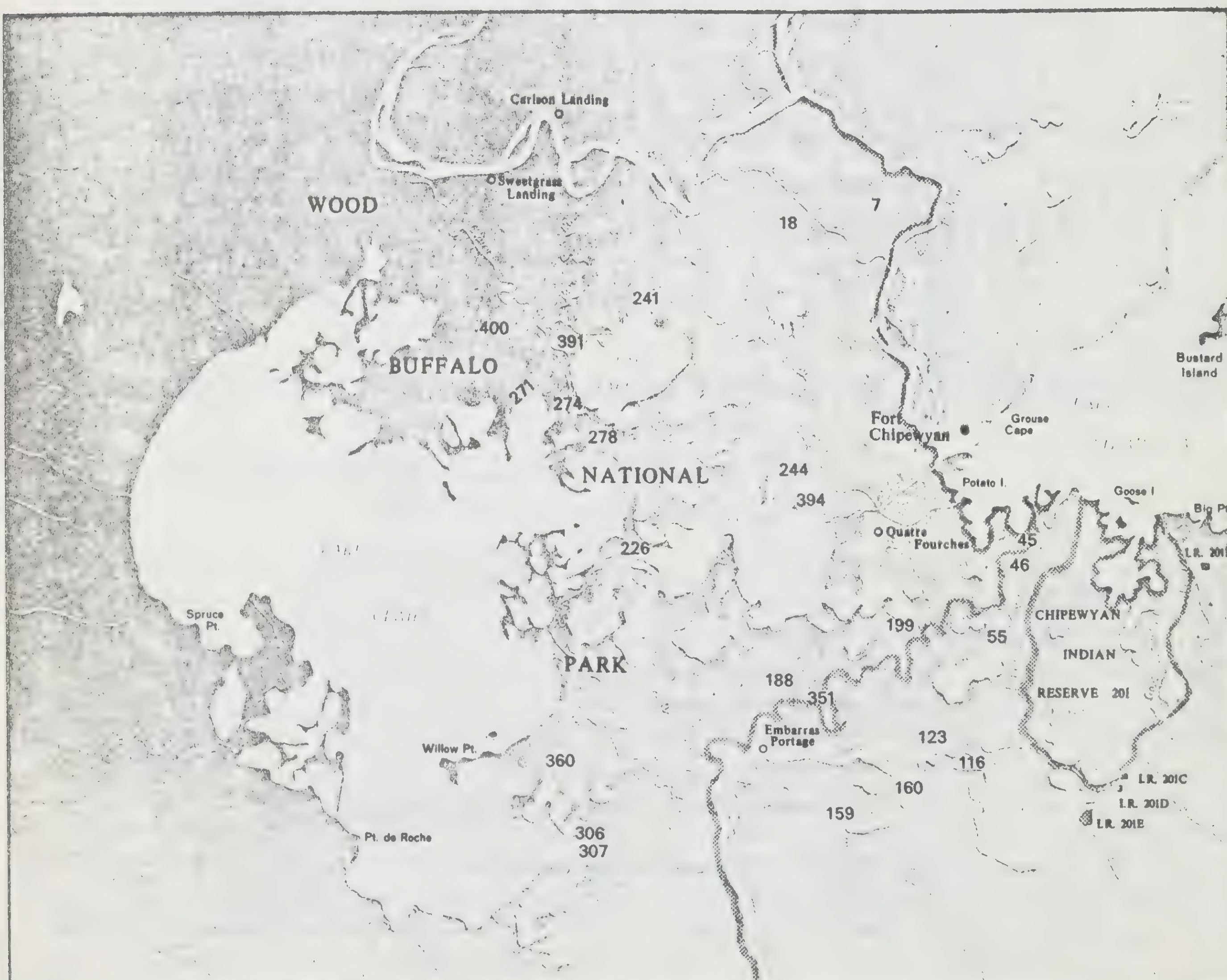


FIGURE 9 Location of Satellite Basins

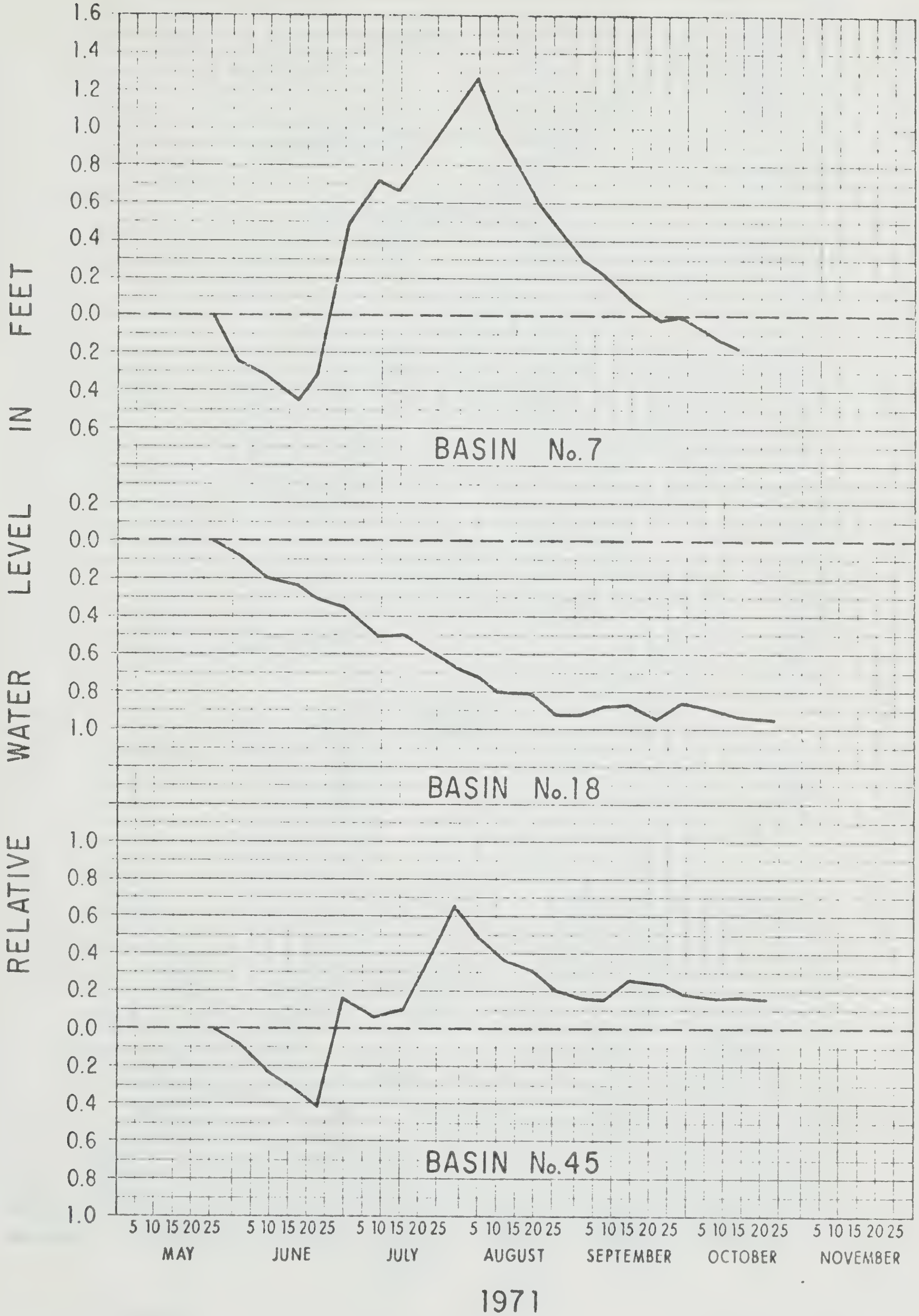
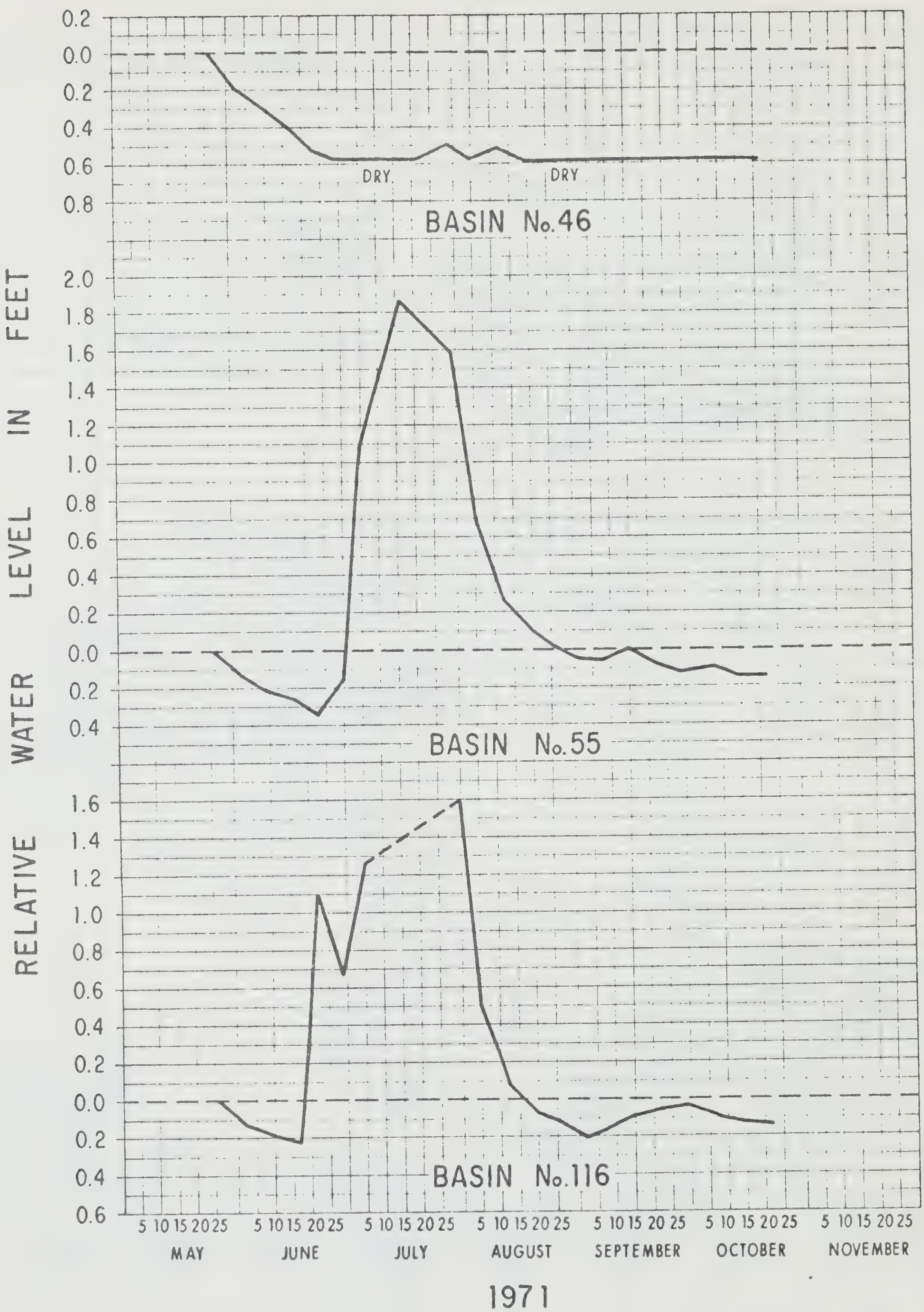
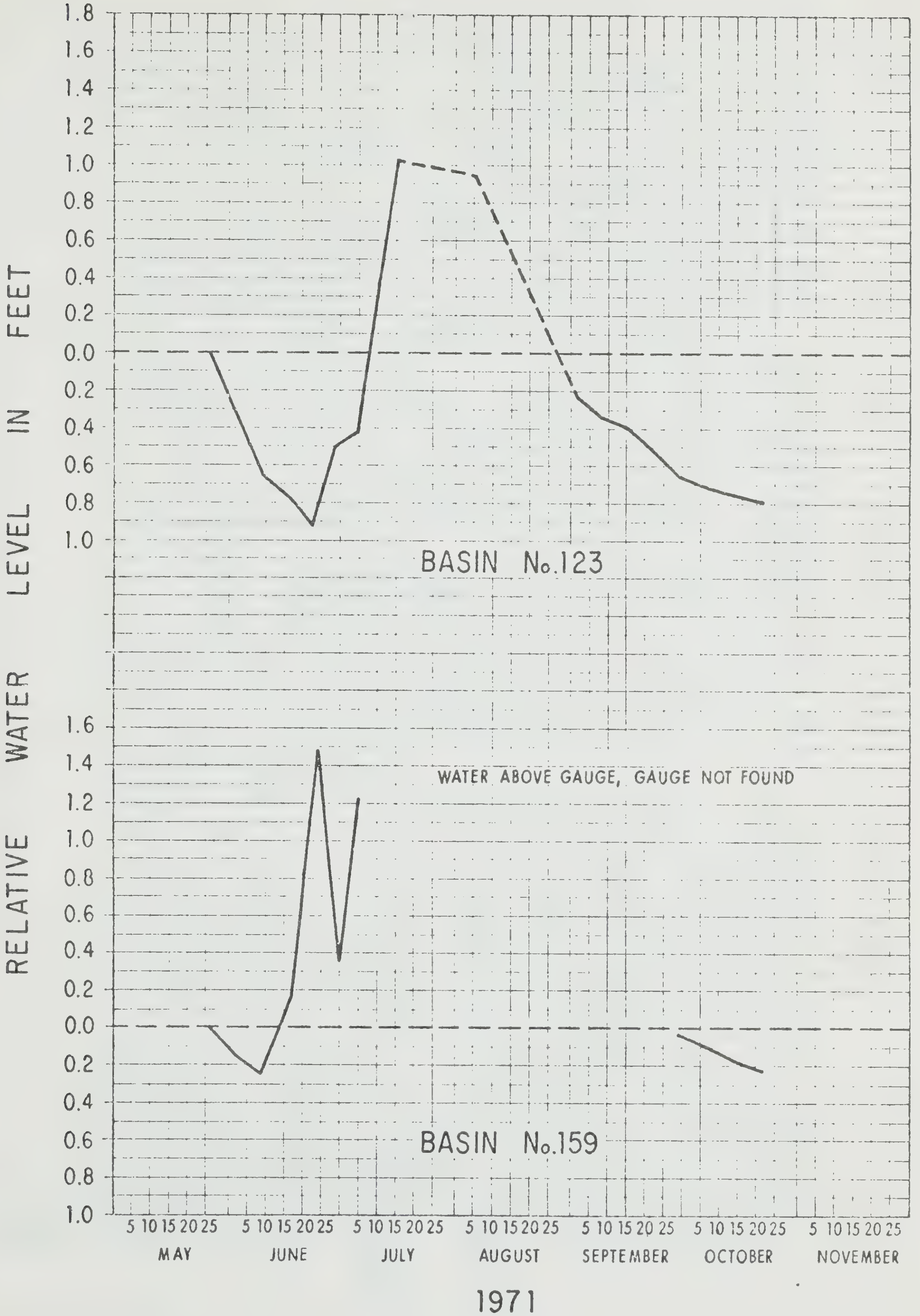

RELATIVE WATER LEVEL IN FEET
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
BASIN No.7
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No.18
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No.45
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.1



RELATIVE WATER LEVEL IN FEET
0.2
0.0
0.2
0.4
0.6
0.8
DRY
DRY
BASIN No.46
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
BASIN No.55
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
BASIN No.116
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.2


RELATIVE WATER LEVEL IN FEET
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1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No.123
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
WATER ABOVE GAUGE, GAUGE NOT FOUND
BASIN No.159
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.3

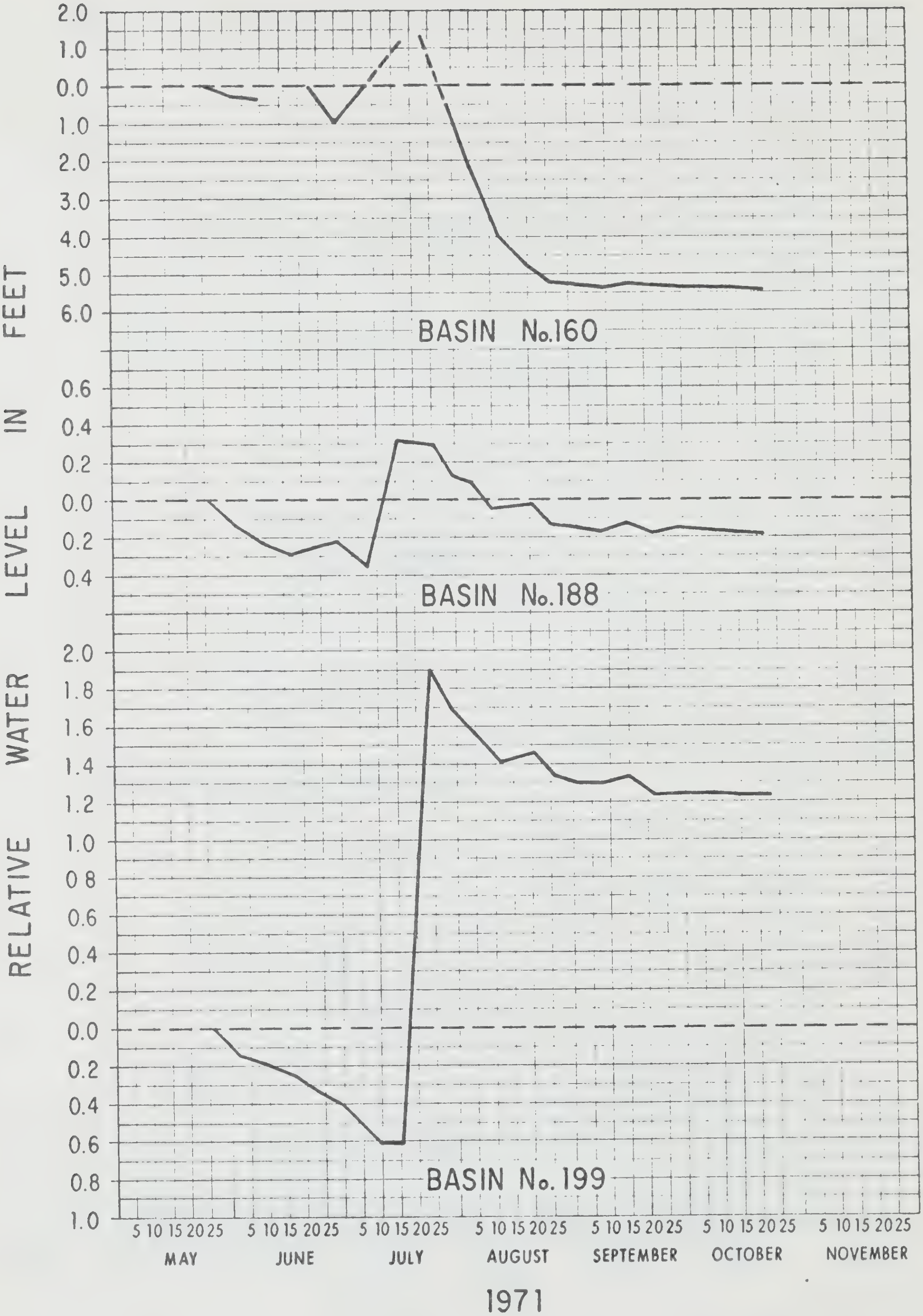
RELATIVE WATER LEVEL IN FEET
2.0
1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
BASIN No.160
0.6
0.4
0.2
0.0
0.2
0.4
BASIN No.188
2.0
1.8
1.6
1.4
1.2
1.0
0 8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No. 199
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.4

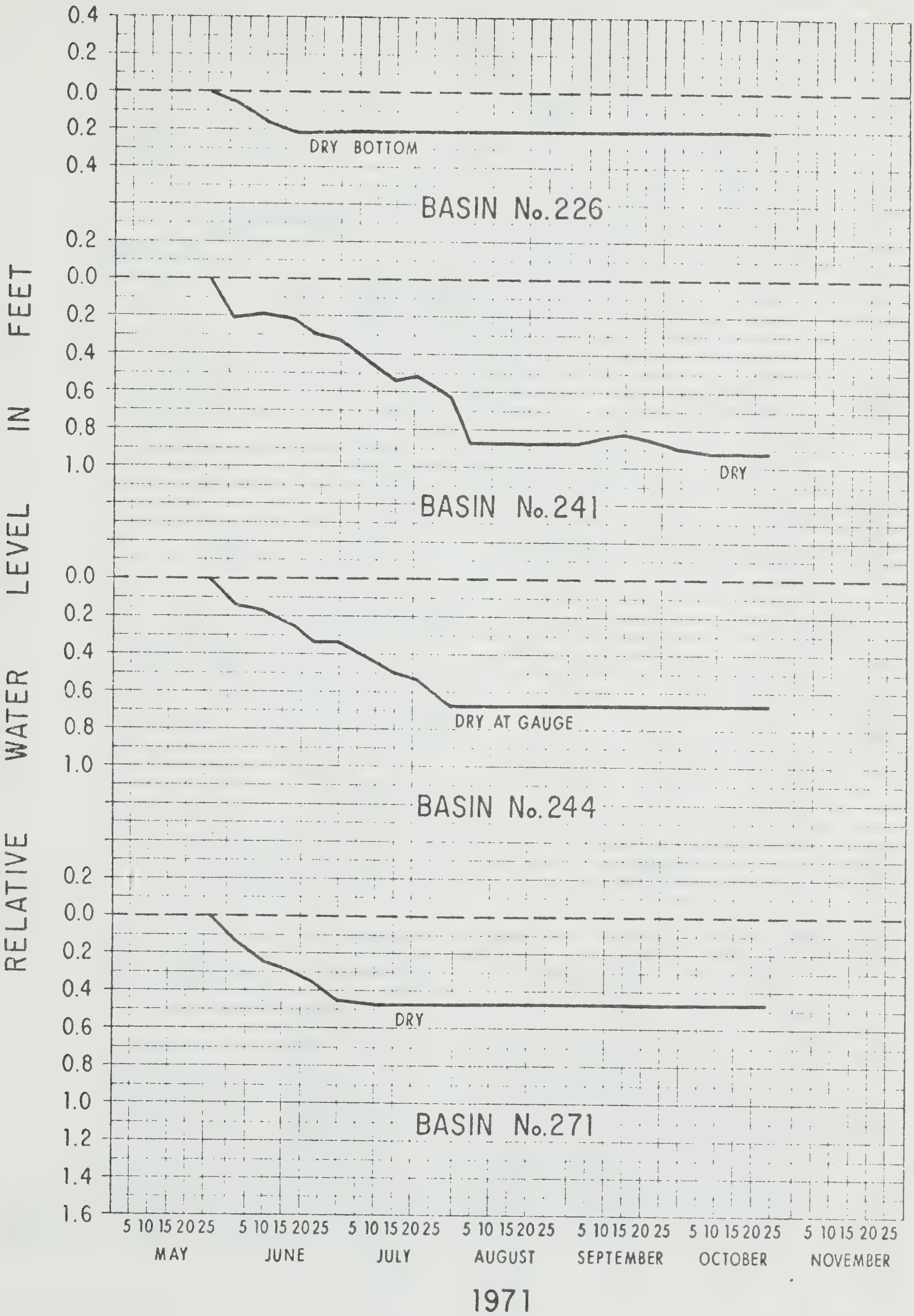
0.4
0.2
0.0
0.2
0.4
DRY BOTTOM
BASIN No. 226
0.2
0.0
0.2
0.4
0.6
0.8
1.0
DRY
BASIN No. 241
0.0
0.2
0.4
0.6
0.8
1.0
DRY AT GAUGE
BASIN No. 244
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
DRY
BASIN No. 271
RELATIVE WATER LEVEL IN FEET
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.5

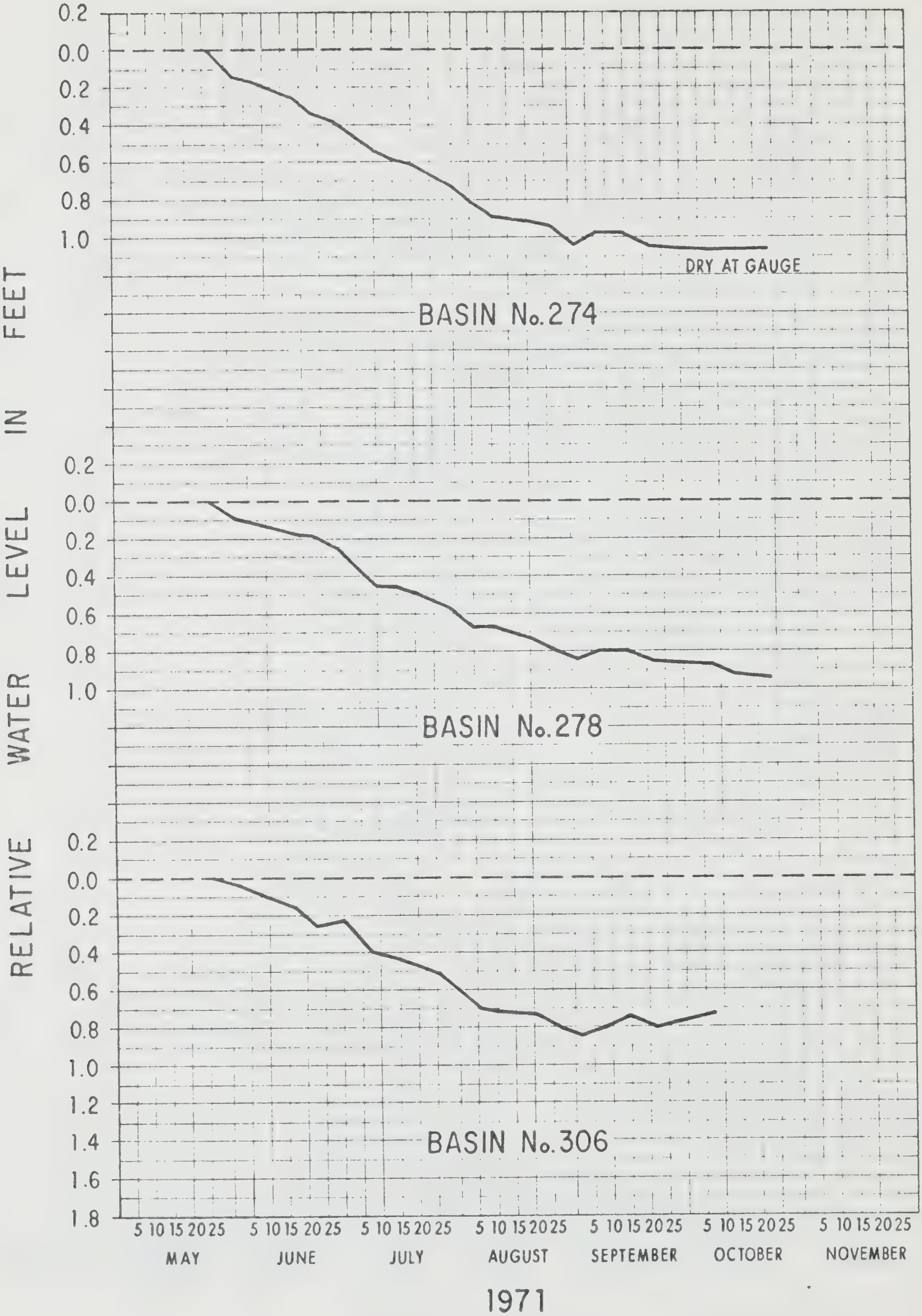
RELATIVE WATER LEVEL IN FEET
0.2
0.0
0.2
0.4
0.6
0.8
1.0
DRY AT GAUGE
BASIN No. 274
BASIN No. 278
1.2
1.4
1.6
1.8
BASIN No. 306
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.6

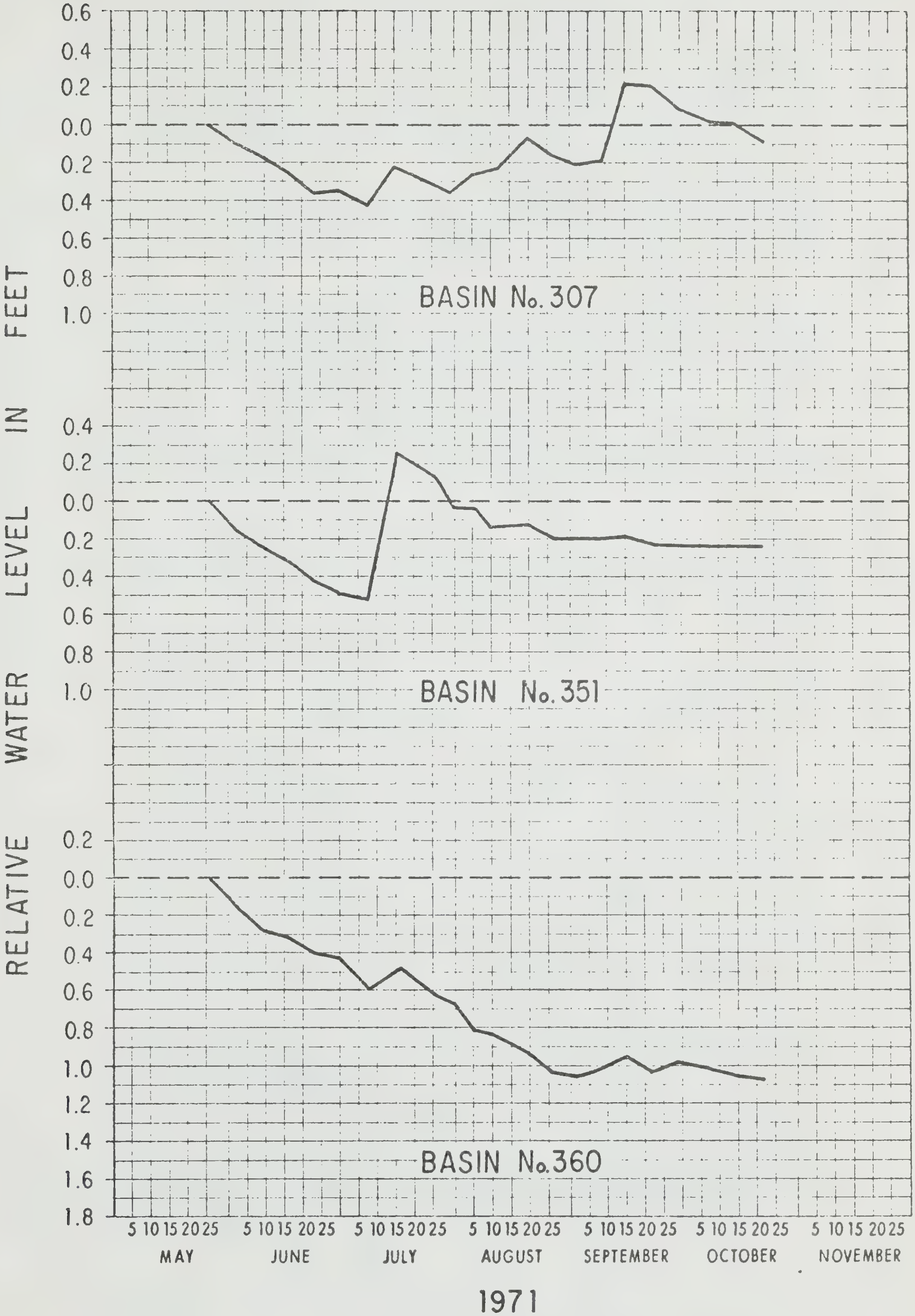
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No. 307
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
BASIN No. 351
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
BASIN No. 360
RELATIVE WATER LEVEL IN FEET
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.7

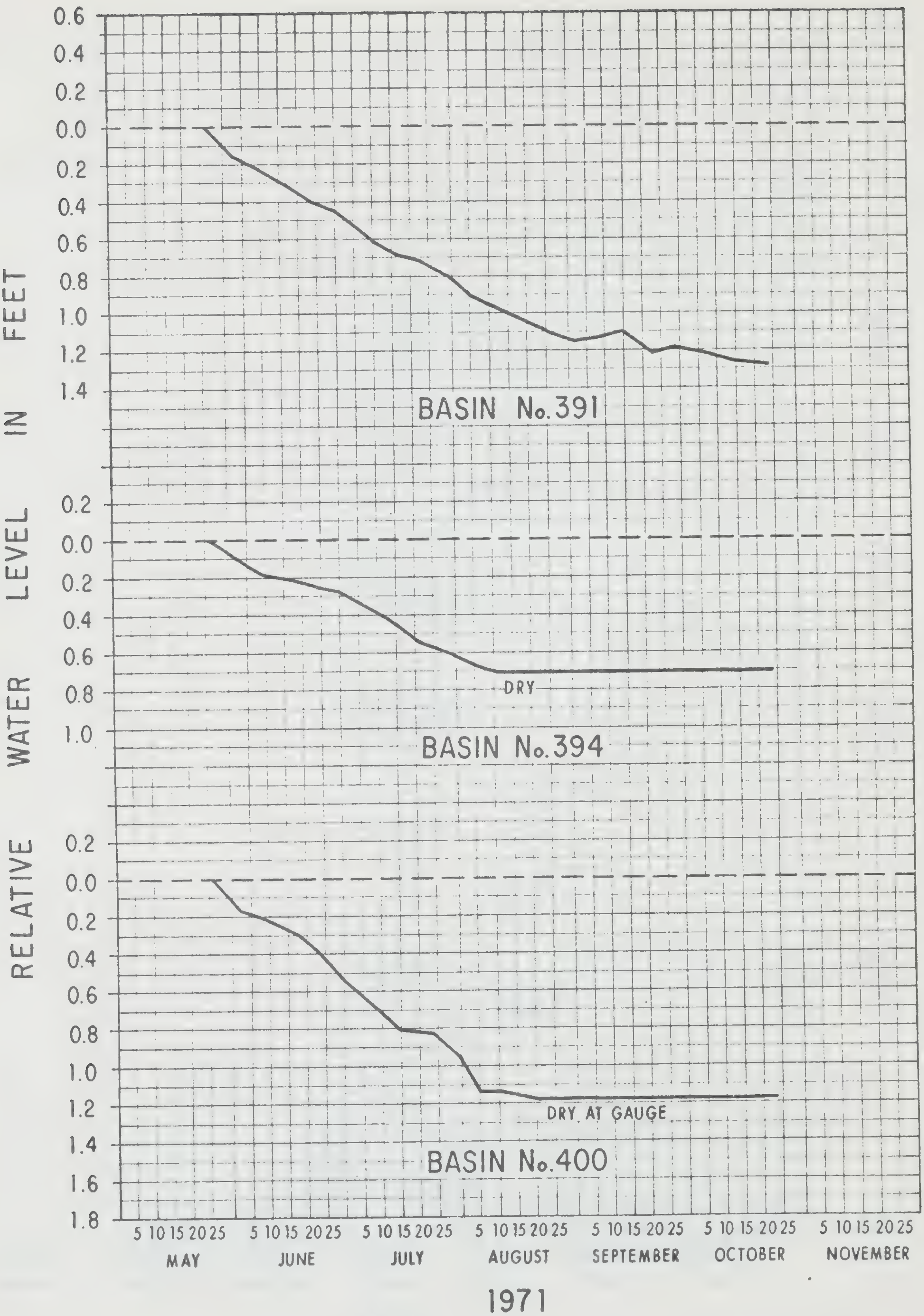
RELATIVE WATER LEVEL IN FEET
BASIN No.391
DRY
BASIN No.394
DRY AT GAUGE
BASIN No.400
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
5 10 15 20 25
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
1971

FIGURE 10.8

APPENDIX A-1

Daily Lake Levels

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.67	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.67	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.62	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.62	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.62	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.62	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.52	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.52	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.42	9
10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.42	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.42	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.27	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	686.17	684.27	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.92	684.27	14
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.27	15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.27	16
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.77	684.27	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.67	684.22	18
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.67	684.22	19
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.67	684.22	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.67	684.17	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.67	684.17	22
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.42	684.17	23
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.42	684.17	24
25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.17	684.17	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.07	684.17	26
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.97	684.17	27
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.87	684.17	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.67	684.17	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.67	684.17	30
31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.17	31
MAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	686.17	684.67	MAX
AVE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	685.49	684.33	AVE
MIN	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.67	684.17	MIN
NO.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	21.	31.	DAY

12 AUG 1970

1931 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1931

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	684.10G	682.90G	681.30G	678.10G	679.90G	685.77	.00	.00	.00	.00	.00	.00	1
2	684.00G	682.80G	681.20G	677.90G	679.92	685.67	.00	.00	.00	.00	.00	.00	2
3	683.92	682.70G	681.10G	677.80G	680.30G	685.52	.00	.00	.00	.00	.00	.00	3
4	683.90G	682.60G	681.00G	677.77	680.70G	685.52	.00	.00	.00	.00	.00	.00	4
5	683.90G	682.50G	680.90G	677.70G	681.10G	685.97	.00	.00	.00	.00	.00	.00	5
6	683.90G	682.40G	680.90	677.70G	681.50G	686.27	.00	.00	.00	.00	.00	.00	6
7	683.90G	682.30G	680.82	677.70G	681.90G	686.62	.00	.00	.00	.00	.00	.00	7
8	683.90G	682.20G	680.80G	677.60G	682.30G	686.77	.00	.00	.00	.00	.00	.00	8
9	683.90G	682.10G	680.70G	677.60G	682.70G	686.87	.00	.00	.00	.00	.00	.00	9
10	683.92	682.00G	680.60G	677.60G	683.10G	686.67	.00	.00	.00	.00	.00	.00	10
11	683.90G	681.90G	680.60G	677.52	683.10G	686.47	.00	.00	.00	.00	.00	.00	11
12	683.90G	681.90G	680.50G	677.80G	683.77	686.72	.00	.00	.00	.00	.00	.00	12
13	683.90G	681.80G	680.50G	678.00G	683.92	686.67	.00	.00	.00	.00	.00	.00	13
14	683.90G	681.30G	680.42	678.20G	684.12	686.57	.00	.00	.00	.00	.00	.00	14
15	683.90G	681.72	680.40G	678.40G	684.27	686.52	.00	.00	.00	.00	.00	.00	15
16	683.90G	681.70G	680.40G	678.60G	684.57	687.47	.00	.00	.00	.00	.00	.00	16
17	683.80	681.70G	680.40G	678.80G	685.37	688.07	.00	.00	.00	.00	.00	.00	17
18	683.80G	681.70G	680.40G	679.07	685.12	687.27	.00	.00	.00	.00	.00	.00	18
19	683.80G	681.70G	680.40G	679.10G	684.77	687.17	.00	.00	.00	.00	.00	.00	19
20	683.80G	681.70G	680.40G	679.10G	684.62	687.17	.00	.00	.00	.00	.00	.00	20
21	683.70G	681.67	679.32	679.20G	684.57	.00	.00	.00	.00	.00	.00	.00	21
22	683.70G	681.60G	679.30G	679.20G	684.97	.00	.00	.00	.00	.00	.00	.00	22
23	683.70G	681.60G	679.30G	679.30G	685.52	.00	.00	.00	.00	.00	.00	.00	23
24	683.67	681.50G	679.20G	679.30G	685.87	.00	.00	.00	.00	.00	.00	.00	24
25	683.60G	681.50G	679.20G	679.32	685.67	.00	.00	.00	.00	.00	.00	.00	25
26	683.50G	681.50G	679.10G	679.40G	685.27	.00	.00	.00	.00	.00	.00	.00	26
27	683.40G	681.47	679.00G	679.50G	684.77	.00	.00	.00	.00	.00	.00	.00	27
28	683.30G	681.40G	678.92	679.60G	684.62	.00	.00	.00	.00	.00	.00	.00	28
29	683.20G	.00	678.70G	679.70G	684.77	.00	.00	.00	.00	.00	.00	.00	29
30	683.10G	.00	678.50G	679.80G	685.32	.00	.00	.00	.00	.00	.00	.00	30
31	683.00G	.00	678.50G	.00	.00	.00	.00	.00	.00	.00	.00	.00	31
MAX	684.10	682.90	681.30	679.80	685.87	688.07	.00	.00	.00	.00	.00	.00	MAX
AVE	683.74	681.94	680.08	678.55	683.61	686.59	.00	.00	.00	.00	.00	.00	AVE
MIN	683.00	681.40	678.50	677.52	679.90	685.52	.00	.00	.00	.00	.00	.00	MIN
NO.	31.	23.	31.	30.	30.	20.	0.	0.	0.	0.	0.	0.	DAY

1934 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1934

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	688.40G	687.20G	685.75	684.30G	683.70G	1
2	.00	.00	.00	.00	.00	.00	.00	688.30G	687.10G	685.40G	684.30G	683.70G	2
3	.00	.00	.00	.00	.00	.00	.00	688.30G	687.10G	685.30G	684.20G	683.70G	3
4	.00	.00	.00	.00	.00	.00	.00	688.20G	687.00G	685.00G	684.20G	683.70G	4
5	.00	.00	.00	.00	.00	.00	.00	688.10G	686.90G	684.97	684.16	683.70G	5
6	.00	.00	.00	.00	.00	.00	.00	688.08	686.88	684.90G	684.10G	683.70G	6
7	.00	.00	.00	.00	.00	.00	.00	688.00G	686.87G	684.90G	684.10G	683.70G	7
8	.00	.00	.00	.00	.00	.00	.00	688.00G	686.86G	684.90G	684.00G	683.70G	8
9	.00	.00	.00	.00	.00	.00	.00	688.00G	686.86G	684.90G	684.00G	683.70G	9
10	.00	.00	.00	.00	.00	.00	.00	688.00G	686.85	684.90G	683.90G	683.64	10
11	.00	.00	.00	.00	.00	.00	.00	688.00G	686.70G	684.90G	683.90G	683.65G	11
12	.00	.00	.00	.00	.00	.00	.00	687.94	686.50G	684.84	683.87	683.65G	12
13	.00	.00	.00	.00	.00	.00	.00	687.94G	686.30G	684.80G	683.85G	683.65G	13
14	.00	.00	.00	.00	.00	.00	.00	687.94G	686.10G	684.80G	683.85G	683.65G	14
15	.00	.00	.00	.00	.00	.00	.00	687.94G	686.00G	684.80G	683.85G	683.65G	15
16	.00	.00	.00	.00	.00	.00	.00	687.94G	685.96	684.70G	683.85G	683.65G	16
17	.00	.00	.00	.00	.00	.00	.00	687.94G	685.90G	684.70G	683.85G	683.66	17
18	.00	.00	.00	.00	.00	.00	.00	687.93	685.90	684.70G	683.85G	683.65G	18
19	.00	.00	.00	.00	.00	.00	.00	687.92G	685.90G	684.61	683.83	683.65G	19
20	.00	.00	.00	.00	.00	.00	.00	687.92G	685.90G	684.50G	683.80G	683.65G	20
21	.00	.00	.00	.00	.00	.00	.00	687.92G	685.90G	684.50G	683.80G	683.65G	21
22	.00	.00	.00	.00	.00	.00	.00	687.90	685.83	684.50G	683.80G	683.65G	22
23	.00	.00	.00	.00	.00	.00	.00	687.80G	685.80G	684.50G	683.80G	683.65G	23
24	.00	.00	.00	.00	.00	.00	.00	687.64	685.80G	684.50G	683.80G	683.64	24
25	.00	.00	.00	.00	.00	.00	.00	687.50G	685.80G	684.50G	683.80G	683.64G	25
26	.00	.00	.00	.00	.00	.00	.00	687.40G	685.80G	684.50G	683.73	683.64G	26
27	.00	.00	.00	.00	.00	.00	.00	687.35	685.80G	684.50G	683.70G	683.64G	27
28	.00	.00	.00	.00	.00	.00	.00	687.30G	685.78	684.50G	683.70G	683.64G	28
29	.00	.00	.00	.00	.00	.00	.00	687.30G	685.75G	684.43	683.70G	683.64G	29
30	.00	.00	.00	.00	.00	.00	.00	687.24	685.75G	684.40G	683.70G	683.64G	30
31	.00	.00	.00	.00	.00	.00	.00	687.20G	.00	684.39	.00	683.63	31
MAX	.00	.00	.00	.00	.00	.00	.00	688.40	687.20	685.75	684.30	683.70	MAX
AVE	.00	.00	.00	.00	.00	.00	.00	687.85	686.29	684.76	683.91	683.66	AVE
MIN	.00	.00	.00	.00	.00	.00	.00	687.20	685.75	684.39	683.70	683.63	MIN
NO.	0.	0.	0.	0.	0.	0.	0.	31.	30.	31.	30.	31.	DAY

1935 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1935

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.60G	682.30G	681.40G	680.20G	678.00G	686.10G	691.50G	691.00G	691.30G	688.40G	685.80G	685.62G	1
2	683.60G	682.30G	681.40G	680.10G	679.00G	686.30G	692.25	691.10G	691.40	688.40G	685.80G	685.61	2
3	683.50G	682.30G	681.40G	680.00G	680.00G	686.59	692.30G	691.30G	691.50G	688.30G	685.80G	685.60G	3
4	683.50G	682.25	681.30G	679.80G	681.00G	686.80G	692.40G	691.50G	691.60G	688.30G	685.76	685.60G	4
5	683.50G	682.20G	681.30G	679.50G	682.00G	687.10G	692.60G	691.65	691.65	688.20G	685.75G	685.60G	5
6	683.40G	682.20G	681.30G	679.20G	683.00G	687.40G	692.80G	691.60G	691.60G	688.20G	685.75G	685.60G	6
7	683.40	682.20G	681.20G	678.90G	684.65	687.60G	692.90G	691.50G	691.40G	688.16	685.75G	685.60G	7
8	683.40G	682.10G	681.20G	678.60G	685.76	687.80G	692.95	691.50G	691.20G	688.10G	685.75G	685.60G	8
9	683.30G	682.10G	681.20G	678.30G	685.48	688.00G	693.00G	691.40G	691.15	688.10G	685.75G	685.55	9
10	683.30G	682.10G	681.10G	678.00G	685.16	688.26	693.00G	691.40G	691.00G	688.00G	685.75G	685.60G	10
11	683.30G	682.00G	681.10G	677.70G	684.21	688.40G	693.10G	691.30G	690.90G	688.00G	685.71	685.60G	11
12	683.20G	682.00G	681.10G	677.40G	684.15	688.60G	693.20G	691.25	690.80G	687.90G	685.70G	685.60G	12
13	683.10G	682.00G	681.00G	677.10G	684.25	688.70G	693.30G	691.25G	690.80G	687.90G	685.70G	685.70G	13
14	683.05	681.90G	681.00G	676.80G	684.40	688.80G	693.35	691.25G	690.70G	687.88	685.70G	685.70G	14
15	683.00G	681.90G	681.00G	676.40G	684.40G	688.90G	693.30G	691.25G	690.70G	687.60G	685.70G	685.70G	15
16	682.90G	681.90G	680.90G	676.00G	684.45	689.00G	693.20G	691.25G	690.62	687.40G	685.70G	685.80	16
17	682.90G	681.80G	680.90G	676.00G	684.57	689.16	693.20G	691.25G	690.50G	687.20G	685.64	685.80G	17
18	682.80G	681.80G	680.90G	676.10G	684.72	689.20G	693.10G	691.25G	690.30G	687.00G	685.64G	685.80G	18
19	682.70G	681.80G	680.80G	676.20G	684.75G	689.40G	693.10G	691.23	690.10G	686.80G	685.64G	685.80G	19
20	682.60G	681.70G	680.80G	676.30G	684.75G	689.60G	693.00G	691.20G	690.00G	686.60G	685.64G	685.80G	20
21	682.55	681.70G	680.80G	676.40G	684.75G	689.80G	693.00G	691.20G	689.90G	686.40	685.64G	685.80G	21
22	682.50G	681.70G	680.70G	676.50G	684.75G	689.90G	692.98	691.20G	689.80G	686.30G	685.64G	685.80G	22
23	682.50G	681.60G	680.70G	676.60G	684.75G	690.00G	692.90G	691.20G	689.65	686.20G	685.64G	685.77	23
24	682.50G	681.60G	680.70G	676.70G	684.75G	690.15	692.90G	691.20G	689.70G	686.10G	685.64G	685.75G	24
25	682.40G	681.60G	680.60G	676.90G	684.77	690.30G	692.90G	691.20G	689.20G	686.00G	685.63	685.75G	25
26	682.40G	681.50G	680.60G	677.10G	684.90G	690.40G	692.90G	691.19	689.00G	685.90G	685.62G	685.75G	26
27	682.40G	681.50G	680.60G	677.30G	685.00G	690.50G	692.90G	691.20G	688.80G	685.80G	685.62G	685.75G	27
28	682.34	681.50G	680.50G	677.50G	685.17	690.60G	692.90G	691.20G	688.60G	685.80	685.62G	685.75G	28
29	682.30G	.00	680.50G	677.70G	685.40G	690.70G	692.84	691.20G	688.50G	685.80G	685.62G	685.75G	29
30	682.30G	.00	680.40G	677.90G	685.60G	690.85G	691.90G	691.20G	688.48	685.80G	685.62G	685.74	30
31	682.30G	.00	680.30G	.00	685.90G	.00	690.95	691.30G	.00	685.80G	.00	685.70G	31
MAX	683.60	682.30	681.40	680.20	685.90	690.85	693.35	691.65	691.65	688.40	685.80	685.80	MAX
AVE	682.92	681.91	680.93	677.64	684.01	688.83	692.79	691.28	690.36	687.17	685.69	685.70	AVE
MIN	682.30	681.50	680.30	676.00	678.00	686.10	690.95	691.00	688.48	685.80	685.62	685.55	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1936 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1936

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.60G	685.70G	682.50G	685.00G	687.00G	689.90G	691.55	691.95	690.20G	689.10G	688.90G	688.75G	1
2	685.50G	685.65G	682.50G	685.00G	687.00G	690.00G	691.45	691.90G	690.20G	689.20G	688.90G	688.75G	2
3	685.40G	685.60G	683.00G	685.00G	687.00G	690.10G	692.10G	691.90G	690.10G	689.30G	688.80G	688.75G	3
4	685.30G	685.40G	683.00G	685.00G	687.00G	690.20G	692.85	691.85	690.10G	689.30G	688.80G	688.76	4
5	685.20G	685.20G	683.00G	685.00G	687.50G	690.30G	691.65	691.85G	690.00G	689.35	688.75	688.70G	5
6	685.16	685.00G	683.00G	685.00G	687.50G	690.40G	691.70G	691.85G	689.95	689.30G	688.75G	688.70G	6
7	685.15G	684.90G	683.00G	685.50G	687.50G	690.50G	691.80G	691.85	690.00G	689.30G	688.75G	688.70F	7
8	685.15G	684.50G	683.00G	685.50G	687.50G	690.50G	691.85	691.80G	690.10G	689.30G	688.75G	688.70G	8
9	685.15G	684.75	683.00G	685.50G	687.50G	690.60G	691.80G	691.80G	690.15	689.20G	688.75G	688.70G	9
10	685.15G	684.60G	683.50G	685.50G	687.50G	690.60G	691.75	690.75	690.70G	689.20G	688.75G	688.70G	10
11	685.15G	682.50G	683.50G	685.50G	687.50G	690.70G	691.75G	691.85	691.20G	689.20G	688.75G	688.70G	11
12	685.15G	682.40G	683.50G	685.50G	688.00G	690.70G	691.75	691.70G	691.80G	689.20G	688.75	688.70G	12
13	685.11	682.30G	683.50G	685.50G	688.00G	690.80G	691.80G	691.60G	692.35	689.15	688.70G	688.70G	13
14	685.10G	682.20G	683.50G	686.00G	688.00G	690.80G	691.90G	691.55	690.15	689.10G	688.70G	688.70G	14
15	685.00G	682.00G	683.50G	686.00G	688.00G	690.90G	692.00G	691.50G	690.10G	689.00G	688.70G	688.70G	15
16	684.90G	681.90G	683.50G	686.00G	688.00G	690.90G	692.05	691.40G	690.00G	689.00G	688.70G	688.70G	16
17	684.80G	681.73	684.00G	686.00G	688.00G	691.00G	692.10G	691.30G	690.00G	689.00G	688.70G	688.70G	17
18	684.70G	682.00G	684.00G	686.00G	688.45	691.05	692.15	691.20G	688.90G	689.00G	688.70G	688.70G	18
19	684.67	682.00G	684.00G	686.00G	688.60G	691.10G	692.10G	691.15	688.90G	689.00G	688.70G	688.70G	19
20	684.65G	682.00G	684.00G	686.00G	688.70G	691.10G	692.05	691.10G	689.80G	689.05	688.65	688.70G	20
21	684.65G	682.00G	684.00G	686.50G	688.80G	691.20G	692.05G	691.00G	689.70G	689.10G	688.70G	688.70G	21
22	684.65G	682.00G	684.00G	686.50G	688.90G	691.20G	692.05G	691.00G	689.75	689.10G	688.70G	688.70G	22
23	684.65G	682.00G	684.00G	686.50G	689.00G	691.30G	692.05G	690.90G	689.70G	689.10G	688.70G	688.70G	23
24	684.65G	682.50G	684.50G	686.50G	689.15	691.30G	692.05	690.90G	689.60G	689.10G	688.70G	688.70G	24
25	684.65G	682.50G	684.50G	686.50G	689.20G	691.40G	692.05G	690.85	689.50G	689.10G	688.70G	688.70G	25
26	684.63	682.50G	684.50G	686.50G	689.30G	691.40G	692.05	690.70G	689.40G	689.10G	688.70G	688.70G	26
27	684.50G	682.50G	684.50G	686.50G	689.40G	691.50G	692.00G	690.60G	689.30G	689.15	688.70G	688.70G	27
28	684.30G	682.50G	684.50G	687.00G	689.50G	691.55	691.95	690.50G	689.20G	689.10G	688.70G	688.70G	28
29	684.10G	.00	684.50G	687.00G	689.60G	692.15	691.80G	690.40G	689.10G	689.10G	688.75	688.70G	29
30	683.90G	.00	684.50G	687.00G	689.70G	691.80G	691.70G	690.35	689.05	689.00G	688.75G	688.70G	30
31	683.80G	.00	685.00G	.00	689.80G	.00	691.65	690.25	.00	689.00G	.00	688.70G	31
MAX	685.60	685.70	685.00	687.00	689.80	692.15	692.85	691.95	692.35	689.35	688.90	688.76	MAX
AVE	684.65	683.24	683.71	685.90	688.28	690.90	691.92	691.27	689.97	689.14	688.73	688.71	AVE
MIN	683.80	681.73	682.50	685.00	687.00	689.90	691.45	690.25	688.90	689.00	688.65	688.70	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1937 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1937

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	687.00G	687.30G	688.15	685.50G	684.90G	685.15	.00	.00	1
2	.00	.00	.00	.00	687.05	687.60G	688.20G	685.90G	685.00G	685.10G	.00	.00	2
3	.00	.00	.00	.00	687.00G	687.90G	688.20G	686.30G	685.20G	685.00G	.00	.00	3
4	.00	.00	.00	.00	687.00G	688.20G	688.20G	686.70G	685.40G	685.00G	.00	.00	4
5	.00	.00	.00	.00	686.90G	688.45	688.20G	687.00G	685.50G	684.90G	.00	.00	5
6	.00	.00	.00	.00	686.90G	688.30G	688.20G	687.35	685.60G	684.90G	.00	.00	6
7	.00	.00	.00	.00	686.85	688.10G	688.20G	687.30G	685.75	684.85	.00	.00	7
8	.00	.00	.00	.00	686.80G	688.00G	688.20G	687.20G	685.70G	684.80G	.00	.00	8
9	.00	.00	.00	.00	686.80G	687.90G	688.25	687.10G	685.70G	684.80G	.00	.00	9
10	.00	.00	.00	.00	686.80G	687.80G	688.25G	687.10G	685.70G	684.80G	.00	.00	10
11	.00	.00	.00	.00	686.70G	687.65	688.25G	687.05	685.70G	684.80G	.00	.00	11
12	.00	.00	.00	.00	686.70G	687.90G	688.25G	687.00G	685.70G	684.80G	.00	.00	12
13	.00	.00	.00	.00	686.65	688.30G	688.25G	686.90G	685.70G	684.80G	.00	.00	13
14	.00	.00	.00	.00	686.70G	688.60G	688.25	686.80G	685.70G	684.80G	.00	.00	14
15	.00	.00	.00	.00	686.70G	688.90G	688.00G	686.80G	685.65	684.80G	.00	.00	15
16	.00	.00	.00	.00	686.70G	689.10G	687.80G	686.70G	685.60G	684.80G	.00	.00	16
17	.00	.00	.00	.00	686.70G	689.35	687.60G	686.70	685.60G	684.80G	.00	.00	17
18	.00	.00	.00	.00	686.80G	688.05	687.40G	686.60G	685.60G	684.80G	.00	.00	18
19	.00	.00	.00	.00	686.80G	688.10G	687.20G	686.50G	685.50G	684.80G	.00	.00	19
20	.00	.00	.00	.00	686.80G	688.20G	686.95	686.45	685.50G	684.70G	.00	.00	20
21	.00	.00	.00	.00	686.85	688.30G	687.20G	687.10G	685.45	684.70G	.00	.00	21
22	.00	.00	.00	.00	686.90G	688.40G	687.50G	687.80G	685.40G	684.70G	.00	.00	22
23	.00	.00	.00	.00	686.90G	688.50G	687.80G	688.55	685.40G	684.70G	.00	.00	23
24	.00	.00	.00	.00	685.90G	688.60G	688.05	685.85	685.40G	684.70G	.00	.00	24
25	.00	.00	.00	.00	686.90G	688.75	687.50G	684.55	685.30G	684.70G	.00	.00	25
26	.00	.00	.00	.00	686.90G	688.60G	687.00G	684.60G	685.30G	684.70G	.00	.00	26
27	.00	.00	.00	.00	687.00G	688.50G	686.40G	684.60G	685.30G	684.70G	.00	.00	27
28	.00	.00	.00	.00	687.00G	688.40G	685.90G	684.70G	685.30G	684.70G	.00	.00	28
29	.00	.00	.00	.00	687.00G	688.30G	685.30G	684.70G	685.25	684.70G	.00	.00	29
30	.00	.00	.00	.00	687.00G	688.20G	684.75	684.75	685.20G	684.70G	.00	.00	30
31	.00	.00	.00	.00	687.05	.00	685.10G	684.80G	.00	684.70G	.00	.00	31
MAX	.00	.00	.00	.00	687.05	689.35	688.25	688.55	685.75	685.15	.00	.00	MAX
AVE	.00	.00	.00	.00	686.86	688.27	687.50	686.35	685.47	684.80	.00	.00	AVE
MIN	.00	.00	.00	.00	686.65	687.30	684.75	684.55	684.90	684.70	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

1938 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1938

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	682.77E	683.49	684.79	684.60G	683.11	683.07E	.00	.00	1
2	.00	.00	.00	.00	682.82E	683.59	685.07E	684.69	683.89	682.73E	.00	.00	2
3	.00	.00	.00	.00	682.89E	683.92E	685.11E	684.79	683.80G	682.49	.00	.00	3
4	.00	.00	.00	.00	682.96E	683.95E	685.29	684.95E	683.70G	683.24E	.00	.00	4
5	.00	.00	.00	.00	683.08E	683.79	685.11E	684.59	683.69	683.12E	.00	.00	5
6	.00	.00	.00	.00	683.16E	683.99	685.29	684.99	683.30E	682.29	.00	.00	6
7	.00	.00	.00	.00	683.17E	684.24E	685.30G	684.85E	683.50G	682.00G	.00	.00	7
8	.00	.00	.00	.00	683.25E	684.28E	685.39	684.69	683.60E	681.80G	.00	.00	8
9	.00	.00	.00	.00	683.28E	684.14	685.29	684.80E	683.69	681.60G	.00	.00	9
10	.00	.00	.00	.00	683.33E	684.39E	685.30G	684.39	683.62E	681.40G	.00	.00	10
11	.00	.00	.00	.00	683.35E	684.29	685.26E	684.70E	683.59	681.20	.00	.00	11
12	.00	.00	.00	.00	683.45E	684.32E	685.19	684.59	683.65E	680.20G	.00	.00	12
13	.00	.00	.00	.00	683.53E	684.39	685.52E	684.62E	683.39	679.20G	.00	.00	13
14	.00	.00	.00	.00	683.50E	684.39	685.09	684.50G	683.60G	678.20	.00	.00	14
15	.00	.00	.00	.00	683.53E	684.45E	685.10G	684.39	683.75G	678.90G	.00	.00	15
16	.00	.00	.00	.00	683.52E	684.39	685.14	684.40G	683.89	679.70G	.00	.00	16
17	.00	.00	.00	.00	683.52E	684.30G	685.44E	684.45E	682.79	680.40G	.00	.00	17
18	.00	.00	.00	.00	683.51E	684.29	685.28E	684.69	683.49	681.20	.00	.00	18
19	.00	.00	.00	.00	682.59	684.65E	685.85	683.49	683.19	681.20G	.00	.00	19
20	.00	.00	.00	.00	682.99	684.67E	685.09	683.80G	683.20G	681.20G	.00	.00	20
21	.00	.00	.00	.00	683.77E	684.77E	685.39E	684.10G	683.30G	681.20	.00	.00	21
22	.00	.00	.00	.00	682.69	684.73E	685.39	684.39	683.31E	681.20G	.00	.00	22
23	.00	.00	.00	.00	683.54E	687.81E	685.30E	684.35E	683.26E	681.20G	.00	.00	23
24	.00	.00	.00	.00	683.53E	685.29	685.30G	684.20G	682.69	681.20G	.00	.00	24
25	.00	.00	.00	.00	682.79	684.70E	685.30E	684.10G	681.84	680.60G	.00	.00	25
26	.00	.00	.00	.00	683.50E	684.80G	685.27E	684.09	682.49	679.90G	.00	.00	26
27	.00	.00	.00	.00	683.67E	684.99	685.32E	683.59	683.15E	679.20	.00	.00	27
28	.00	.00	.00	.00	682.59	684.93E	684.29	683.80G	683.21E	679.20G	.00	.00	28
29	.00	.00	.00	.00	683.59	685.14	683.29	684.19	683.12E	679.20G	.00	.00	29
30	.00	.00	.00	.00	683.47E	684.94E	684.59	683.90G	682.69	679.20	.00	.00	30
31	.00	.00	.00	.00	683.53E	.00	684.60G	683.60G	.00	679.20G	.00	.00	31
MAX	.00	.00	.00	.00	683.77	687.81	685.85	684.99	683.89	683.24	.00	.00	MAX
AVE	.00	.00	.00	.00	683.25	684.53	685.13	684.36	683.36	680.85	.00	.00	AVE
MIN	.00	.00	.00	.00	682.59	683.49	683.29	683.49	682.49	678.20	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

1939 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1939

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	682.59	684.80G	686.26E	686.35	685.50E	683.99	.00	.00	1
2	.00	.00	.00	.00	682.50G	684.79	686.30E	686.80E	685.25E	683.90G	.00	.00	2
3	.00	.00	.00	.00	682.50G	685.04E	686.35E	686.70E	685.79	683.89	.00	.00	3
4	.00	.00	.00	.00	682.49	685.15E	686.65	686.45	684.65E	683.90G	.00	.00	4
5	.00	.00	.00	.00	682.40G	685.15E	686.40E	686.65E	683.59	683.90G	.00	.00	5
6	.00	.00	.00	.00	682.40G	685.16E	686.25	686.60E	683.90G	683.90G	.00	.00	6
7	.00	.00	.00	.00	682.39	685.85	686.45	686.15	684.40G	683.89	.00	.00	7
8	.00	.00	.00	.00	682.60G	685.30E	686.35E	686.40E	684.99	683.90G	.00	.00	8
9	.00	.00	.00	.00	682.80G	685.25	686.30G	686.20	685.18E	683.88E	.00	.00	9
10	.00	.00	.00	.00	682.90G	685.48E	686.15	686.40E	685.28E	683.88E	.00	.00	10
11	.00	.00	.00	.00	683.00G	685.80E	686.35E	686.45	684.69	683.90E	.00	.00	11
12	.00	.00	.00	.00	683.09	685.70E	684.65	686.30E	685.00E	683.92E	.00	.00	12
13	.00	.00	.00	.00	682.89	685.80E	686.75	686.40E	685.00E	683.90E	.00	.00	13
14	.00	.00	.00	.00	682.89	685.35	686.25	685.85	684.89	683.80G	.00	.00	14
15	.00	.00	.00	.00	683.79	686.15	686.45E	685.65	684.49	683.70E	.00	.00	15
16	.00	.00	.00	.00	684.19	685.90E	686.45E	684.50G	684.95E	683.75E	.00	.00	16
17	.00	.00	.00	.00	683.50E	685.94E	686.25	683.39	684.85E	683.50E	.00	.00	17
18	.00	.00	.00	.00	683.67E	685.94E	686.50E	685.05	683.69	683.60E	.00	.00	18
19	.00	.00	.00	.00	682.89	686.45	686.05	686.15E	684.34	683.65E	.00	.00	19
20	.00	.00	.00	.00	683.49E	686.15E	686.25	686.10E	684.89	683.60E	.00	.00	20
21	.00	.00	.00	.00	683.67E	686.10E	686.46E	685.85	684.49	683.50E	.00	.00	21
22	.00	.00	.00	.00	683.70E	686.55	686.47E	686.05E	684.49	683.65E	.00	.00	22
23	.00	.00	.00	.00	685.15	686.05E	686.40E	685.95E	685.59	683.68E	.00	.00	23
24	.00	.00	.00	.00	684.70G	686.15	686.05	685.55	684.49	683.63E	.00	.00	24
25	.00	.00	.00	.00	684.29	686.00E	686.15	685.75	684.59	683.54E	.00	.00	25
26	.00	.00	.00	.00	683.99	686.65	686.65E	685.70E	684.44	683.65E	.00	.00	26
27	.00	.00	.00	.00	685.00G	686.05E	686.65	685.60	684.29	683.50E	.00	.00	27
28	.00	.00	.00	.00	685.95	686.55	686.60E	685.60E	683.79	683.90E	.00	.00	28
29	.00	.00	.00	.00	685.70G	686.25E	686.60G	685.10E	683.69	683.80E	.00	.00	29
30	.00	.00	.00	.00	685.29	686.20E	686.65E	685.50E	684.09	684.00E	.00	.00	30
31	.00	.00	.00	.00	685.00G	.00	687.05	685.49	.00	683.30E	.00	.00	31
MAX	.00	.00	.00	.00	685.95	686.65	687.05	686.80	685.79	684.00	.00	.00	MAX
AVE	.00	.00	.00	.00	683.59	685.80	686.36	685.91	684.64	683.76	.00	.00	AVE
MIN	.00	.00	.00	.00	682.39	684.79	684.65	683.39	683.39	683.30	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

1940 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1940

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	684.35	686.20E	687.60G	687.25	686.08E	684.61	.00	.00	1
2	.00	.00	.00	.00	684.55	686.38E	686.65	687.35	685.90E	684.67	.00	.00	2
3	.00	.00	.00	.00	684.55	686.50E	687.55	687.10G	685.80E	684.04	.00	.00	3
4	.00	.00	.00	.00	685.05	686.52E	687.35	686.85	685.70E	683.67	.00	.00	4
5	.00	.00	.00	.00	685.15	686.45E	687.80E	685.85	685.80E	683.79	.00	.00	5
6	.00	.00	.00	.00	685.15	686.60G	687.70E	686.55	685.75E	683.79	.00	.00	6
7	.00	.00	.00	.00	684.85	686.70E	687.60G	687.15	685.75E	683.79	.00	.00	7
8	.00	.00	.00	.00	684.86E	686.55	687.60G	687.10E	685.30	683.64	.00	.00	8
9	.00	.00	.00	.00	684.96E	686.65	687.60G	687.00E	685.35	683.39	.00	.00	9
10	.00	.00	.00	.00	684.15	686.75	687.50G	687.00E	685.10	683.54	.00	.00	10
11	.00	.00	.00	.00	684.20G	688.55	687.50G	687.00E	684.60	683.44	.00	.00	11
12	.00	.00	.00	.00	684.25	688.45	687.50G	687.00E	685.05	683.29	.00	.00	12
13	.00	.00	.00	.00	684.25	686.45	687.50G	687.00E	684.85	683.50E	.00	.00	13
14	.00	.00	.00	.00	684.40G	686.45	687.50G	686.95E	684.40	683.49	.00	.00	14
15	.00	.00	.00	.00	684.65	686.60G	687.40G	686.80E	685.00	683.50E	.00	.00	15
16	.00	.00	.00	.00	684.85	686.80G	687.40G	686.75E	684.65	683.50E	.00	.00	16
17	.00	.00	.00	.00	684.95	687.05	687.40G	686.75E	684.50	683.57	.00	.00	17
18	.00	.00	.00	.00	684.90G	686.85	687.40G	686.55	684.65	683.25E	.00	.00	18
19	.00	.00	.00	.00	684.85	687.15	687.35	686.35	684.65	683.05E	.00	.00	19
20	.00	.00	.00	.00	685.05	687.00G	687.25	686.50	683.74	683.20E	.00	.00	20
21	.00	.00	.00	.00	685.10G	686.95	687.35	686.95	684.79	683.25E	.00	.00	21
22	.00	.00	.00	.00	685.20G	687.25G	687.35	686.40E	684.69	683.25E	.00	.00	22
23	.00	.00	.00	.00	685.25	687.55	687.35	686.40	685.04	683.00E	.00	.00	23
24	.00	.00	.00	.00	685.30G	687.95	687.35	686.35	684.49	683.00E	.00	.00	24
25	.00	.00	.00	.00	685.40G	688.25	687.35	686.20	684.29	683.30E	.00	.00	25
26	.00	.00	.00	.00	685.50G	687.45	687.45	686.05	684.44	683.30E	.00	.00	26
27	.00	.00	.00	.00	685.65	687.55	687.40G	685.85	684.69	682.90G	.00	.00	27
28	.00	.00	.00	.00	685.70G	687.55	687.35	686.00	684.94	682.50E	.00	.00	28
29	.00	.00	.00	.00	685.90G	687.50E	687.25	685.85	683.64	682.75E	.00	.00	29
30	.00	.00	.00	.00	686.15	687.75	687.15	686.00	684.64	682.80E	.00	.00	30
31	.00	.00	.00	.00	686.15E	687.60E	686.35	685.05	.00	682.75E	.00	.00	31
MAX	.00	.00	.00	.00	686.15	688.55	687.80	687.35	686.08	684.67	.00	.00	MAX
AVE	.00	.00	.00	.00	685.01	687.10	687.38	686.58	684.94	683.40	.00	.00	AVE
MIN	.00	.00	.00	.00	684.15	686.20	686.35	685.05	683.64	682.50	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	31.	31.	31.	30.	31.	0.	0.	DAY

12 AUG 1970

LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	684.20E	685.07	686.30	686.00E	684.70G	684.15G	.00	.00	1
2	.00	.00	.00	.00	684.10E	684.80	685.90	685.80G	684.70G	684.15G	.00	.00	2
3	.00	.00	.00	.00	684.20E	684.80	685.85	685.40	684.70G	684.15G	.00	.00	3
4	.00	.00	.00	.00	684.20E	684.65	685.95	684.95	684.68E	684.15G	.00	.00	4
5	.00	.00	.00	.00	684.20E	685.10	685.85	685.60	684.63E	684.15G	.00	.00	5
6	.00	.00	.00	.00	684.20E	684.77	685.80	685.85	684.58E	684.15G	.00	.00	6
7	.00	.00	.00	.00	684.20E	685.05	685.82	685.75	684.53E	684.15G	.00	.00	7
8	.00	.00	.00	.00	684.20E	684.80	686.95	686.10	684.48E	684.15G	.00	.00	8
9	.00	.00	.00	.00	684.20E	684.85	686.25	685.40	684.38E	684.15G	.00	.00	9
10	.00	.00	.00	.00	684.75	684.40	686.10	685.25	684.38E	684.15G	.00	.00	10
11	.00	.00	.00	.00	683.63	685.00	686.20	685.75	684.28E	684.15G	.00	.00	11
12	.00	.00	.00	.00	683.77	685.15	685.95	686.00	684.23E	684.15G	.00	.00	12
13	.00	.00	.00	.00	683.43	685.13	685.85	684.95	684.18E	684.15G	.00	.00	13
14	.00	.00	.00	.00	683.57	685.17	686.25	685.58E	684.08E	684.15G	.00	.00	14
15	.00	.00	.00	.00	683.67	685.33	686.20	685.50G	684.03E	684.15G	.00	.00	15
16	.00	.00	.00	.00	683.80	685.45	685.90	685.50G	683.98E	684.15G	.00	.00	16
17	.00	.00	.00	.00	683.77	685.37	686.05	685.50G	683.98E	684.15G	.00	.00	17
18	.00	.00	.00	.00	684.00	685.50	686.15	685.48E	683.98E	684.15G	.00	.00	18
19	.00	.00	.00	.00	683.25	685.40	686.20	685.48E	684.00G	684.15G	.00	.00	19
20	.00	.00	.00	.00	684.70E	686.05	687.35	685.38E	684.00G	684.15G	.00	.00	20
21	.00	.00	.00	.00	683.80	685.60	687.30	685.28E	684.08E	684.15G	.00	.00	21
22	.00	.00	.00	.00	684.33	685.50	686.30	685.24E	684.18E	684.15G	.00	.00	22
23	.00	.00	.00	.00	684.70	686.60	688.15	685.08E	684.18E	684.15G	.00	.00	23
24	.00	.00	.00	.00	684.57	685.25	686.90	685.08E	684.18E	684.15G	.00	.00	24
25	.00	.00	.00	.00	684.70	685.58E	685.85	685.08E	684.13E	684.15G	.00	.00	25
26	.00	.00	.00	.00	684.95	687.40	687.35	685.05G	684.15G	684.15G	.00	.00	26
27	.00	.00	.00	.00	684.67	685.63E	685.96E	685.05G	684.15G	684.15E	.00	.00	27
28	.00	.00	.00	.00	684.75	685.90G	685.98E	685.03E	684.15G	684.12E	.00	.00	28
29	.00	.00	.00	.00	684.77	686.15	686.00E	684.98E	684.15G	684.15E	.00	.00	29
30	.00	.00	.00	.00	685.00	686.00	686.00G	684.88E	684.15G	684.20E	.00	.00	30
31	.00	.00	.00	.00	685.03	.00	686.00G	684.78E	684.15G	684.25E	.00	.00	31
MAX	.00	.00	.00	.00	685.03	687.40	688.15	686.10	684.70	684.25	.00	.00	MAX
AVE	.00	.00	.00	.00	684.24	685.38	686.28	685.38	684.26	684.15	.00	.00	AVE
MIN	.00	.00	.00	.00	683.25	684.40	685.80	684.78	683.98	684.12	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	31.	31.	0.	0.	DAY

12 AUG 1970

LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	683.80E	685.35	688.55	687.35	686.45	684.85	.00	.00	1
2	.00	.00	.00	.00	683.98E	685.75	689.15	687.65	686.45	684.90	.00	.00	2
3	.00	.00	.00	.00	684.00E	685.75	688.75	687.70	686.20	684.90	.00	.00	3
4	.00	.00	.00	.00	684.10E	686.85	688.35	687.50	685.85	684.90	.00	.00	4
5	.00	.00	.00	.00	684.25E	686.80	688.35	687.55	685.45	684.00G	.00	.00	5
6	.00	.00	.00	.00	684.40E	686.75	688.35	687.65	685.45	683.55	.00	.00	6
7	.00	.00	.00	.00	684.45E	686.95	688.30	687.65	685.05	683.60	.00	.00	7
8	.00	.00	.00	.00	684.50E	687.30	688.30	687.65	685.65	683.75	.00	.00	8
9	.00	.00	.00	.00	684.50E	687.80	688.25	687.50	685.70	683.85	.00	.00	9
10	.00	.00	.00	.00	684.50E	688.55	688.25	686.95	685.65	683.50	.00	.00	10
11	.00	.00	.00	.00	684.55E	686.75	688.65	687.15	684.85	.00	.00	.00	11
12	.00	.00	.00	.00	684.25	686.85	688.25	687.15	685.75	.00	.00	.00	12
13	.00	.00	.00	.00	684.25	687.60	688.55	687.00	684.80	.00	.00	.00	13
14	.00	.00	.00	.00	684.25	687.70	688.30	686.80	685.75	.00	.00	.00	14
15	.00	.00	.00	.00	684.35	687.55	688.45	686.75	685.75	.00	.00	.00	15
16	.00	.00	.00	.00	684.45	688.00	688.45	686.75	685.75	.00	.00	.00	16
17	.00	.00	.00	.00	684.45	689.15	688.05	686.75	685.60	.00	.00	.00	17
18	.00	.00	.00	.00	684.65	688.65	688.05	685.15	684.80	.00	.00	.00	18
19	.00	.00	.00	.00	684.65	688.55	687.90	686.65	684.75	.00	.00	.00	19
20	.00	.00	.00	.00	684.95	687.65	688.05	686.65	684.60	.00	.00	.00	20
21	.00	.00	.00	.00	685.50	687.65	688.25	686.65	685.75	.00	.00	.00	21
22	.00	.00	.00	.00	686.90	688.05	688.05	686.65	685.20	.00	.00	.00	22
23	.00	.00	.00	.00	685.10	687.80	687.85	686.65	685.45	.00	.00	.00	23
24	.00	.00	.00	.00	685.20	688.35	687.85	685.75	685.20	.00	.00	.00	24
25	.00	.00	.00	.00	685.05	688.15	687.75	685.65	685.05	.00	.00	.00	25
26	.00	.00	.00	.00	685.40	687.65	687.75	686.35	684.95	.00	.00	.00	26
27	.00	.00	.00	.00	687.35	688.15	687.75	686.45	685.05	.00	.00	.00	27
28	.00	.00	.00	.00	686.25	688.35	687.75	686.40	685.75	.00	.00	.00	28
29	.00	.00	.00	.00	685.00	688.25	687.65	685.75	684.50	.00	.00	.00	29
30	.00	.00	.00	.00	685.50	688.40	687.70	686.35	684.45	.00	.00	.00	30
31	.00	.00	.00	.00	685.15	.00	687.65	686.45	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	687.35	689.15	689.15	687.70	686.45	684.90	.00	.00	MAX
AVE	.00	.00	.00	.00	684.83	687.57	688.17	686.81	685.39	684.18	.00	.00	AVE
MIN	.00	.00	.00	.00	683.80	685.35	687.65	685.15	684.45	683.50	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	10.	0.	0.	DAY

12 AUG 1970

1943 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1943

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	685.45	685.40	687.65	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	684.85	685.05	688.15	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	684.55	687.90	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	683.95	684.45	688.20	.00	.00	.00	.00	.00	4
5	.00	.00	.00	.00	.00	685.05	687.90	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	684.75	688.35	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	684.75	688.25	.00	.00	.00	.00	.00	7
8	.00	.00	.00	.00	Below Gauge .00	684.75	688.40	.00	.00	.00	.00	.00	8
9	.00	.00	.00	.00	.00	685.25	688.30	.00	.00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	684.75	688.20	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	684.75	687.95	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	684.85	687.55	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	684.75	688.05	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	683.35	685.85	688.05	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	683.65	685.40	687.95	.00	.00	.00	.00	.00	15
16	.00	.00	.00	.00	683.85	685.75	687.95	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	684.05	685.85	687.85	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	684.15	686.20	687.65	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	684.65	686.05	687.65	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	684.35	685.80	687.65	.00	.00	.00	.00	.00	20
21	.00	.00	.00	.00	684.25	685.85	687.20	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	684.65	686.85	687.65	.00	.00	.00	.00	.00	22
23	.00	.00	.00	.00	683.70	688.05	687.65	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	684.35	687.25	687.65	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	683.95	687.25	687.75	.00	.00	.00	.00	.00	25
26	.00	.00	.00	.00	684.35	686.95	688.05	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	684.55	687.25	687.87	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	684.55	686.00	687.60	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	685.25	686.95	687.35	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	685.25	687.25	687.23	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	684.95	.00	687.85	.00	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	685.45	688.05	688.40	.00	.00	.00	.00	.00	MAX
AVE	.00	.00	.00	.00	684.39	685.79	687.85	.00	.00	.00	.00	.00	AVE
MIN	.00	.00	.00	.00	683.35	684.45	687.20	.00	.00	.00	.00	.00	MIN
NO.	0.	0.	0.	0.	21.	30.	31.	0.	0.	0.	0.	0.	DAY

12 AUG 1970

1944 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1944

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	685.47	686.57	685.07	683.42	.00	.00	.00	1
2	.00	.00	.00	.00	Below Gauge .00	684.48	686.42	685.32	683.38	.00	.00	.00	2
3	.00	.00	.00	.00	.00	685.12	686.32	685.52	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	685.77	686.22	685.27	683.47	.00	.00	.00	4
5	.00	.00	.00	.00	.00	684.47	685.87	685.27	683.57	.00	.00	.00	5
6	.00	.00	.00	.00	.00	685.42	685.17	685.22	683.57	.00	.00	.00	6
7	.00	.00	.00	.00	.00	685.17	685.57	685.17	683.57	.00	.00	.00	7
8	.00	.00	.00	.00	.00	685.17	685.67	685.17	683.47	.00	.00	.00	8
9	.00	.00	.00	.00	682.63	685.17	685.37	685.07	683.57	.00	.00	.00	9
10	.00	.00	.00	.00	Below Gauge .00	685.27	685.87	684.97	683.67	.00	.00	.00	10
11	.00	.00	.00	.00	.00	685.37	685.97	684.97	683.67	.00	.00	.00	11
12	.00	.00	.00	.00	.00	685.87	685.47	684.92	683.67	.00	.00	.00	12
13	.00	.00	.00	.00	.00	686.22	685.57	684.92	683.60G	.00	.00	.00	13
14	.00	.00	.00	.00	683.38	686.56	685.57	685.07	683.60G	.00	.00	.00	14
15	.00	.00	.00	.00	.00	685.77	685.57	684.97	683.50G	.00	.00	.00	15
16	.00	.00	.00	.00	683.43	685.67	685.67	684.87	683.50G	.00	.00	.00	16
17	.00	.00	.00	.00	683.23	686.77	685.77	684.87	683.40G	.00	.00	.00	17
18	.00	.00	.00	.00	683.33	686.27	685.77	684.87	683.40G	.00	.00	.00	18
19	.00	.00	.00	.00	683.23	686.87	686.07	684.77	683.30G	.00	.00	.00	19
20	.00	.00	.00	.00	Below Gauge .00	686.57	686.37	684.77	683.30G	.00	.00	.00	20
21	.00	.00	.00	.00	.00	686.57	685.77	684.67	683.20G	.00	.00	.00	21
22	.00	.00	.00	.00	.00	686.57	685.77	684.37	683.20G	.00	.00	.00	22
23	.00	.00	.00	.00	.00	686.57	685.47	683.46	683.10G	.00	.00	.00	23
24	.00	.00	.00	.00	.00	686.57	685.27	683.46	683.00G	.00	.00	.00	24
25	.00	.00	.00	.00	.00	686.47	685.27	683.45	682.90G	.00	.00	.00	25
26	.00	.00	.00	.00	682.37	686.37	685.27	683.42	682.90G	.00	.00	.00	26
27	.00	.00	.00	.00	683.92	686.37	685.17	683.42	682.80G	.00	.00	.00	27
28	.00	.00	.00	.00	683.77	686.47	685.17	683.42	682.80G	.00	.00	.00	28
29	.00	.00	.00	.00	BG .00	686.47	685.27	683.38	682.77	.00	.00	.00	29
30	.00	.00	.00	.00	.00	686.57	685.17	683.38	682.74	.00	.00	.00	30
31	.00	.00	.00	.00	684.80	.00	685.17	683.38	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	684.80	686.87	686.57	685.52	683.67	.00	.00	.00	MAX
AVE	.00	.00	.00	.00	683.41	685.95	685.67	684.54	683.31	.00	.00	.00	AVE
MIN	.00	.00	.00	.00	682.37	684.47	685.17	683.38	682.74	.00	.00	.00	MIN
NO.	0.	0.	0.	0.	10.	30.	31.	31.	29.	0.	0.	0.	DAY

20 AUG 1970

1945	LAKE ATHABASCA AT FORT CHIPEWYAN	07MD001	1945

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	683.80G	684.05	683.71	682.51	.00	.00	.00	1
2	.00	.00	.00	.00	.00	683.80G	683.84	683.76	682.67	.00	.00	.00	2
3	.00	.00	.00	.00	.00	683.87	683.76	683.71	682.93	.00	.00	.00	3
4	.00	.00	.00	.00	.00	683.59	683.72	683.63	683.65	.00	.00	.00	4
5	.00	.00	.00	.00	.00	683.59	683.63	683.55	684.09	.00	.00	.00	5
6	.00	.00	.00	.00	.00	683.59	683.67	683.55	683.63	.00	.00	.00	6
7	.00	.00	.00	.00	.00	683.59	683.76	683.47	683.13	.00	.00	.00	7
8	.00	.00	.00	.00	.00	684.25	683.95	683.42	682.59	.00	.00	.00	8
9	.00	.00	.00	.00	.00	684.84	683.95	683.38	Below Gauge .00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	684.38	684.01	683.34	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	684.59	684.05	683.43	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	684.47	684.12	684.09	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	684.15	683.84	684.09	682.13	.00	.00	.00	13
14	.00	.00	.00	.00	.00	684.09	683.72	683.92	682.88	.00	.00	.00	14
15	.00	.00	.00	.00	.00	684.29	683.59	683.59	683.09	.00	.00	.00	15
16	.00	.00	.00	.00	.00	684.01	684.15	683.26	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	683.95	684.12	683.19	681.88	.00	.00	.00	17
18	.00	.00	.00	.00	.00	683.95	684.09	683.23	683.34	.00	.00	.00	18
19	.00	.00	.00	.00	.00	684.34	684.15	.00	683.05	.00	.00	.00	19
20	.00	.00	.00	.00	.00	684.05	683.87	BG .00	682.84	.00	.00	.00	20
21	.00	.00	.00	.00	.00	683.84	684.25	.00	683.09	.00	.00	.00	21
22	.00	.00	.00	.00	.00	684.01	683.59	681.92	682.59	.00	.00	.00	22
23	.00	.00	.00	.00	.00	684.05	683.38	681.92	682.13	.00	.00	.00	23
24	.00	.00	.00	.00	.00	684.09	683.76	681.84	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	684.09	683.80	681.92	Below Gauge .00	.00	.00	.00	25
26	.00	.00	.00	.00	.00	684.15	683.76	681.84	.00	.00	.00	.00	26
27	.00	.00	.00	.00	.00	684.29	683.72	681.92	.00	.00	.00	.00	27
28	.00	.00	.00	.00	.00	684.84	683.63	682.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	684.92	683.59	682.26	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	684.20	683.63	682.55	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	683.63	682.55	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	.00	684.92	684.25	684.09	684.09	.00	.00	.00	MAX
AVE	.00	.00	.00	.00	.00	684.12	683.83	683.04	682.90	.00	.00	.00	AVE
MIN	.00	.00	.00	.00	.00	683.59	683.38	681.84	681.88	.00	.00	.00	MIN
NO.	0.	0.	0.	0.	0.	30.	31.	28.	18.	0.	0.	0.	DAY

LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	682.46	685.17	684.76	684.50	683.88	.00	.00	.00	1
2	.00	.00	.00	.00	682.46	685.34	685.00	684.09	683.84	.00	.00	.00	2
3	.00	.00	.00	.00	681.97	685.51	685.09	684.46	683.21	.00	.00	.00	3
4	.00	.00	.00	.00	Below Gauge .00	685.67	684.88	684.39	683.92	.00	.00	.00	4
5	.00	.00	.00	.00	.00	685.96	684.96	684.88	683.84	.00	.00	.00	5
6	.00	.00	.00	.00	.00	685.80	685.13	684.96	683.42	.00	.00	.00	6
7	.00	.00	.00	.00	.00	685.51	685.13	685.14	683.01	.00	.00	.00	7
8	.00	.00	.00	.00	682.38	685.35	684.84	685.00	682.92	.00	.00	.00	8
9	.00	.00	.00	.00	682.88	685.19	684.71	685.17	683.01	.00	.00	.00	9
10	.00	.00	.00	.00	683.35	685.19	685.01	684.96	683.00	.00	.00	.00	10
11	.00	.00	.00	.00	683.05	685.19	685.09	684.92	683.04	.00	.00	.00	11
12	.00	.00	.00	.00	682.59	685.51	684.95	684.80	683.00	.00	.00	.00	12
13	.00	.00	.00	.00	682.71	685.51	685.00	685.05	682.84	.00	.00	.00	13
14	.00	.00	.00	.00	683.01	684.84	684.84	684.79	682.92	.00	.00	.00	14
15	.00	.00	.00	.00	683.39	685.09	685.13	684.92	682.88	.00	.00	.00	15
16	.00	.00	.00	.00	683.89	685.09	684.59	684.92	683.46	.00	.00	.00	16
17	.00	.00	.00	.00	684.19	685.09	685.00	684.21	683.09	.00	.00	.00	17
18	.00	.00	.00	.00	683.80	685.09	684.75	684.50	682.67	.00	.00	.00	18
19	.00	.00	.00	.00	683.84	684.67	684.67	684.34	682.88	.00	.00	.00	19
20	.00	.00	.00	.00	683.92	684.83	684.92	684.25	682.63	.00	.00	.00	20
21	.00	.00	.00	.00	684.13	685.51	685.71	684.34	682.88	.00	.00	.00	21
22	.00	.00	.00	.00	683.92	685.51	686.09	684.13	682.84	.00	.00	.00	22
23	.00	.00	.00	.00	683.59	685.51	684.76	683.84	682.63	.00	.00	.00	23
24	.00	.00	.00	.00	685.05	684.84	684.67	683.92	682.59	.00	.00	.00	24
25	.00	.00	.00	.00	685.39	685.88	684.80	683.88	683.84	.00	.00	.00	25
26	.00	.00	.00	.00	685.17	685.09	684.21	684.09	683.76	.00	.00	.00	26
27	.00	.00	.00	.00	685.09	684.84	685.06	684.14	683.76	.00	.00	.00	27
28	.00	.00	.00	.00	685.39	685.00	685.00	683.71	683.42	.00	.00	.00	28
29	.00	.00	.00	.00	685.09	684.92	684.92	683.42	.00	.00	.00	.00	29
30	.00	.00	.00	.00	685.01	684.88	684.64	684.09	.00	.00	.00	.00	30
31	.00	.00	.00	.00	685.17	.00	684.59	683.92	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	685.39	685.96	686.09	685.17	683.92	.00	.00	.00	MAX
AVE	.00	.00	.00	.00	683.81	685.25	684.93	684.44	683.18	.00	.00	.00	AVE
MIN	.00	.00	.00	.00	681.97	684.67	684.21	683.42	682.59	.00	.00	.00	MIN
NO.	0.	0.	0.	0.	27.	30.	31.	31.	28.	0.	0.	0.	DAY

1947 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1947

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	685.50G	686.33	688.78	687.17	685.94	684.97	.00	.00	1
2	.00	.00	.00	.00	685.60G	686.29	688.55	687.53	686.10	684.99	.00	.00	2
3	.00	.00	.00	.00	685.70G	686.43	688.53	687.33	686.16	684.82	.00	.00	3
4	.00	.00	.00	.00	685.80G	686.65	688.75	687.13	685.85	684.40G	.00	.00	4
5	.00	.00	.00	.00	685.90G	686.77	688.66	687.05	686.03	684.13	.00	.00	5
6	.00	.00	.00	.00	686.18	687.07	688.79	687.29	686.15	684.39	.00	.00	6
7	.00	.00	.00	.00	686.28	686.97	688.47	687.35	686.04	684.83	.00	.00	7
8	.00	.00	.00	.00	686.92	686.95	688.42	687.27	686.35	684.81	.00	.00	8
9	.00	.00	.00	.00	685.95	686.91	687.54	687.43	686.37	684.79	.00	.00	9
10	.00	.00	.00	.00	685.28	686.90	688.39	687.29	686.23	684.71	.00	.00	10
11	.00	.00	.00	.00	684.95	687.14	688.29	687.11	686.11	684.65	.00	.00	11
12	.00	.00	.00	.00	685.10	687.35	687.77	687.06	685.97	684.70G	.00	.00	12
13	.00	.00	.00	.00	685.14	687.29	688.03	687.26	685.38	684.74	.00	.00	13
14	.00	.00	.00	.00	685.16	687.44	687.57	687.22	685.40G	684.75	.00	.00	14
15	.00	.00	.00	.00	685.68	687.46G	688.49	687.17	685.46	684.77	.00	.00	15
16	.00	.00	.00	.00	685.55	687.48	687.96	686.96	685.43	684.77	.00	.00	16
17	.00	.00	.00	.00	685.60G	689.06	687.67	686.91	685.31	684.72	.00	.00	17
18	.00	.00	.00	.00	685.70	687.77	687.59	686.68	685.16	684.13	.00	.00	18
19	.00	.00	.00	.00	685.67	687.60	687.65	686.55	684.93	684.31	.00	.00	19
20	.00	.00	.00	.00	686.26	687.75	687.34	686.57	684.87	684.27	.00	.00	20
21	.00	.00	.00	.00	685.89	687.90	687.65	686.67	684.99	684.28	.00	.00	21
22	.00	.00	.00	.00	686.02	688.15	687.54	686.73	684.91	684.21	.00	.00	22
23	.00	.00	.00	.00	686.35	688.41	688.02	686.41	684.89	684.29	.00	.00	23
24	.00	.00	.00	.00	686.27	688.39	687.57	686.37	684.93	684.34	.00	.00	24
25	.00	.00	.00	.00	686.34	689.12	687.57	686.29	684.97	684.17	.00	.00	25
26	.00	.00	.00	.00	686.11	688.43	687.50	686.29	684.97	684.24	.00	.00	26
27	.00	.00	.00	.00	686.16	688.38	687.58	686.29	684.95	684.25	.00	.00	27
28	.00	.00	.00	.00	686.30	688.29	687.99	686.43	684.95	684.20	.00	.00	28
29	.00	.00	.00	.00	686.35	688.60	687.99	686.23	684.41	684.19	.00	.00	29
30	.00	.00	.00	.00	686.39	688.54	686.97	686.15	684.76	684.17	.00	.00	30
31	.00	.00	.00	.00	686.34	.00	687.18	685.91	.00	684.13	.00	.00	31
MAX	.00	.00	.00	.00	686.92	689.12	688.79	687.53	686.37	684.99	.00	.00	MAX
AVE	.00	.00	.00	.00	685.89	687.59	687.96	686.84	685.47	684.49	.00	.00	AVE
MIN	.00	.00	.00	.00	684.95	686.29	686.97	685.91	684.41	684.13	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

12 AUG 1970

1948 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1948

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	688.49	689.19	688.70	686.83	686.57	.00	.00	1
2	.00	.00	.00	.00	.00	688.61	689.13	688.67	686.73	686.60	.00	.00	2
3	.00	.00	.00	.00	.00	688.90	689.06	688.49	686.32	686.60	.00	.00	3
4	.00	.00	.00	.00	.00	688.99	689.04	689.42	686.82	686.49	.00	.00	4
5	.00	.00	.00	.00	.00	689.07	689.06	688.47	687.05	686.58	.00	.00	5
6	.00	.00	.00	.00	.00	689.14	688.99	688.46	687.24	685.23	.00	.00	6
7	.00	.00	.00	.00	.00	689.33	688.99	688.45	687.31	684.17	.00	.00	7
8	.00	.00	.00	.00	.00	689.71	689.01	688.35	686.93	683.74	.00	.00	8
9	.00	.00	.00	.00	682.05	690.27	689.03	688.26	687.11	684.93	.00	.00	9
10	.00	.00	.00	.00	683.17	690.40G	689.09	688.15	686.65	685.84	.00	.00	10
11	.00	.00	.00	.00	685.85	690.60G	689.16	688.04	687.09	684.97	.00	.00	11
12	.00	.00	.00	.00	685.74	690.70G	689.26	687.47	687.04	684.19	.00	.00	12
13	.00	.00	.00	.00	685.13	690.80G	689.33	686.88	687.01	685.15	.00	.00	13
14	.00	.00	.00	.00	684.81	690.92	689.41	687.46	687.11	686.40	.00	.00	14
15	.00	.00	.00	.00	684.70	690.90G	689.43	687.34	687.22	685.64	.00	.00	15
16	.00	.00	.00	.00	685.25	690.92	689.43	687.29	687.29	685.21	.00	.00	16
17	.00	.00	.00	.00	685.67	690.91	689.43	687.24	687.22	685.16	.00	.00	17
18	.00	.00	.00	.00	685.35	690.90	689.41	687.86	687.06	685.10	.00	.00	18
19	.00	.00	.00	.00	685.51	690.81	689.39	687.32	687.02	685.00	.00	.00	19
20	.00	.00	.00	.00	685.81	690.71	689.36	686.95	686.92	684.95	.00	.00	20
21	.00	.00	.00	.00	687.31	690.55	689.24	687.32	686.53	685.05	.00	.00	21
22	.00	.00	.00	.00	687.43	690.39	689.13	687.56	686.62	685.07	.00	.00	22
23	.00	.00	.00	.00	687.54	690.07	688.96	687.15	686.77	685.04	.00	.00	23
24	.00	.00	.00	.00	687.37	690.05	688.80	686.80G	685.83	684.78	.00	.00	24
25	.00	.00	.00	.00	686.99	689.80G	688.69	686.45	685.01	684.29	.00	.00	25
26	.00	.00	.00	.00	686.92	689.57	688.57	686.98	685.02	684.55	.00	.00	26
27	.00	.00	.00	.00	687.13	689.48	688.53	688.27	685.12	684.77	.00	.00	27
28	.00	.00	.00	.00	687.43	689.35	688.59	687.16	686.19	684.48	.00	.00	28
29	.00	.00	.00	.00	686.68	689.25	688.55	687.52	686.45	684.16	.00	.00	29
30	.00	.00	.00	.00	687.81	689.19	688.52	687.38	686.49	683.95	.00	.00	30
31	.00	.00	.00	.00	688.11	.00	688.48	686.81	.00	684.00G	.00	.00	31
MAX	.00	.00	.00	.00	688.11	690.92	689.43	689.42	687.31	686.60	.00	.00	MAX
AVE	.00	.00	.00	.00	686.08	689.96	689.04	687.70	686.67	685.12	.00	.00	AVE
MIN	.00	.00	.00	.00	682.05	688.49	688.48	686.45	685.01	683.74	.00	.00	MIN
NO.	0.	0.	0.	0.	23.	30.	31.	31.	30.	31.	0.	0.	DAY

1949 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1949

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	683.61	685.25	685.90	686.33	685.55	684.07	.00	.00	1
2	.00	.00	.00	.00	683.45	684.93	685.90	685.90	685.60	683.43	.00	.00	2
3	.00	.00	.00	.00	684.37	684.80	686.35	686.30	685.40	683.75	.00	.00	3
4	.00	.00	.00	.00	683.23	684.33	686.95	686.45	685.47	684.65	.00	.00	4
5	.00	.00	.00	.00	683.14	685.05	686.27	686.20	685.45	684.07	.00	.00	5
6	.00	.00	.00	.00	683.17	685.47	686.07	686.23	685.37	684.55	.00	.00	6
7	.00	.00	.00	.00	682.95	684.03	686.17	686.35	685.20	683.70	.00	.00	7
8	.00	.00	.00	.00	683.60	684.85	686.25	687.00	686.00	683.77	.00	.00	8
9	.00	.00	.00	.00	683.98	685.77	686.45	686.77	687.17	683.65	.00	.00	9
10	.00	.00	.00	.00	683.70	685.40	686.50	686.45	686.25	683.70	.00	.00	10
11	.00	.00	.00	.00	684.10	685.40	686.33	686.50	685.35	683.75	.00	.00	11
12	.00	.00	.00	.00	684.45	685.63	686.25	686.50	685.13	683.80	.00	.00	12
13	.00	.00	.00	.00	684.45	685.70	686.40	686.27	685.10	683.63	.00	.00	13
14	.00	.00	.00	.00	683.77	685.67	686.47	685.95	685.00	683.53	.00	.00	14
15	.00	.00	.00	.00	684.00	685.85	686.37	685.85	685.07	683.00	.00	.00	15
16	.00	.00	.00	.00	683.60	685.97	686.25	686.15	685.15	682.60	.00	.00	16
17	.00	.00	.00	.00	684.03	686.03	686.13	686.17	684.85	682.15	.00	.00	17
18	.00	.00	.00	.00	685.09	686.27	686.40	685.30	684.75	682.80	.00	.00	18
19	.00	.00	.00	.00	684.50	685.93	685.83	685.90	684.60	682.30	.00	.00	19
20	.00	.00	.00	.00	683.90	685.85	686.20	685.83	684.23	683.00	.00	.00	20
21	.00	.00	.00	.00	684.23	686.40	686.13	685.95	684.33	683.00	.00	.00	21
22	.00	.00	.00	.00	684.25	686.13	686.35	685.93	684.50	683.40	.00	.00	22
23	.00	.00	.00	.00	684.23	686.00	686.03	686.15	684.45	683.25	.00	.00	23
24	.00	.00	.00	.00	684.23	687.07	686.20	686.17	684.20	682.45	.00	.00	24
25	.00	.00	.00	.00	684.30	686.70	686.10	685.50	683.73	682.30	.00	.00	25
26	.00	.00	.00	.00	684.80	686.90	685.95	685.77	683.93	682.80	.00	.00	26
27	.00	.00	.00	.00	684.67	686.20	685.83	685.67	684.35	682.85	.00	.00	27
28	.00	.00	.00	.00	684.70	685.73	686.05	685.85	684.05	682.70	.00	.00	28
29	.00	.00	.00	.00	684.95	686.05	686.00	685.70	684.40	682.60	.00	.00	29
30	.00	.00	.00	.00	684.55	686.07	685.75	685.50	684.60	682.50	.00	.00	30
31	.00	.00	.00	.00	685.25	.00	686.25	685.27	.00	682.73	.00	.00	31
MAX	.00	.00	.00	.00	685.25	687.07	686.95	687.00	687.17	684.65	.00	.00	MAX
AVE	.00	.00	.00	.00	684.10	685.71	686.20	686.06	684.97	683.24	.00	.00	AVE
MIN	.00	.00	.00	.00	682.95	684.03	685.75	685.27	683.73	682.15	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

1950 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1950

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	684.50G	685.15	687.15	686.05	684.70	682.75	.00	.00	1
2	.00	.00	.00	.00	684.80G	685.35	687.05	685.75	684.60	683.30	.00	.00	2
3	.00	.00	.00	.00	685.00G	685.15	686.95	684.95	684.75	682.90	.00	.00	3
4	.00	.00	.00	.00	685.25	685.00	686.80	685.80	683.50	683.10	.00	.00	4
5	.00	.00	.00	.00	683.35	684.77	686.95	685.80	684.05	682.95	.00	.00	5
6	.00	.00	.00	.00	684.50	684.90	687.25	685.95	683.85	682.65	.00	.00	6
7	.00	.00	.00	.00	683.95	684.95	686.60	686.10	683.73	682.85	.00	.00	7
8	.00	.00	.00	.00	684.10	684.80	686.45	685.75	684.15	682.80	.00	.00	8
9	.00	.00	.00	.00	683.80	685.35	686.85	685.65	683.85	683.05	.00	.00	9
10	.00	.00	.00	.00	684.00	685.20	686.95	685.80	684.20	683.00	.00	.00	10
11	.00	.00	.00	.00	683.83	685.06	686.85	685.75	684.80	682.75	.00	.00	11
12	.00	.00	.00	.00	683.77	685.05	686.85	685.70	684.45	682.65	.00	.00	12
13	.00	.00	.00	.00	683.60	685.16	686.90	685.90	684.00	682.90	.00	.00	13
14	.00	.00	.00	.00	684.20	685.17	686.65	686.05	684.70	682.60	.00	.00	14
15	.00	.00	.00	.00	684.10	685.12	686.25	685.30	683.75	682.45	.00	.00	15
16	.00	.00	.00	.00	684.03	685.45	686.65	685.15	684.00	682.40	.00	.00	16
17	.00	.00	.00	.00	684.45	685.43	686.55	685.55	683.75	682.15	.00	.00	17
18	.00	.00	.00	.00	684.55	685.80	686.70	685.35	683.60	682.15	.00	.00	18
19	.00	.00	.00	.00	684.17	686.05	686.70	685.30	683.05	682.20	.00	.00	19
20	.00	.00	.00	.00	684.33	686.10	686.35	685.20	683.45	682.15	.00	.00	20
21	.00	.00	.00	.00	684.40	686.50	686.50	685.10	682.90	682.15	.00	.00	21
22	.00	.00	.00	.00	684.65	686.30	686.55	685.00	683.05	682.15	.00	.00	22
23	.00	.00	.00	.00	684.60	686.35	686.65	685.20	683.00	682.15	.00	.00	23
24	.00	.00	.00	.00	684.75	686.30	686.40	685.00	683.15	682.15	.00	.00	24
25	.00	.00	.00	.00	684.57	686.40	686.10	685.10	683.35	682.15	.00	.00	25
26	.00	.00	.00	.00	684.40	686.80	686.30	685.25	683.50	682.15	.00	.00	26
27	.00	.00	.00	.00	684.73	686.45	686.35	684.95	682.90	682.15	.00	.00	27
28	.00	.00	.00	.00	684.80	686.60	686.05	684.85	682.73	682.15	.00	.00	28
29	.00	.00	.00	.00	684.60	686.85	686.10	684.55	682.55	682.15	.00	.00	29
30	.00	.00	.00	.00	684.95	687.10	685.80	684.55	682.70	682.15	.00	.00	30
31	.00	.00	.00	.00	685.00	.00	685.95	684.75	.00	682.15	.00	.00	31
MAX	.00	.00	.00	.00	685.25	687.10	687.25	686.10	684.80	683.30	.00	.00	MAX
AVE	.00	.00	.00	.00	684.38	685.69	686.59	685.39	683.69	682.50	.00	.00	AVE
MIN	.00	.00	.00	.00	683.35	684.77	685.80	684.55	682.55	682.15	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	31.	0.	0.	DAY

12 AUG 1970

1951 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1951

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	684.20G	687.45	688.00	688.13	685.77	684.65	.00	.00	1
2	.00	.00	.00	.00	684.40G	687.90	688.33	688.47	686.07	684.57	.00	.00	2
3	.00	.00	.00	.00	684.45	688.17	688.10	688.25	686.27	684.43	.00	.00	3
4	.00	.00	.00	.00	684.60	688.15	688.15	687.90	685.97	684.35	.00	.00	4
5	.00	.00	.00	.00	684.20	688.15	688.27	688.15	686.30	684.23	.00	.00	5
6	.00	.00	.00	.00	684.00	687.87	688.10	688.25	686.00	684.45	.00	.00	6
7	.00	.00	.00	.00	684.20	688.25	687.90	688.13	686.00	684.65	.00	.00	7
8	.00	.00	.00	.00	684.45	687.85	688.20	687.83	686.07	684.80	.00	.00	8
9	.00	.00	.00	.00	684.60	687.95	688.20	687.73	685.87	685.03	.00	.00	9
10	.00	.00	.00	.00	684.70	687.85	687.92	687.45	685.20	685.25	.00	.00	10
11	.00	.00	.00	.00	684.90	688.45	687.99	687.45	685.40	685.35	.00	.00	11
12	.00	.00	.00	.00	685.00	688.35	688.23	687.35	685.60	683.57	.00	.00	12
13	.00	.00	.00	.00	685.05	688.15	688.25	687.45	685.30	683.63	.00	.00	13
14	.00	.00	.00	.00	685.30	688.15	688.33	687.40	685.20	684.13	.00	.00	14
15	.00	.00	.00	.00	685.35	688.10	688.07	687.40	685.37	684.65	.00	.00	15
16	.00	.00	.00	.00	685.55	688.10G	687.87	687.33	685.45	684.15	.00	.00	16
17	.00	.00	.00	.00	686.00	688.13	688.25	687.17	686.25	683.55	.00	.00	17
18	.00	.00	.00	.00	686.20	688.10	688.25	687.35	685.65	683.25	.00	.00	18
19	.00	.00	.00	.00	686.25	688.35	688.07	686.95	685.70	682.30	.00	.00	19
20	.00	.00	.00	.00	686.25	688.17	688.25	686.70	685.62	682.15	.00	.00	20
21	.00	.00	.00	.00	686.65	688.40	688.25	686.50	685.53	.00	.00	.00	21
22	.00	.00	.00	.00	686.35	688.23	688.20	686.58	685.43	.00	.00	.00	22
23	.00	.00	.00	.00	686.60	687.97	688.27	686.75	685.63	.00	.00	.00	23
24	.00	.00	.00	.00	686.93	688.20	688.00	686.75	685.77	.00	.00	.00	24
25	.00	.00	.00	.00	686.87	688.55	688.13	686.27	685.60	.00	.00	.00	25
26	.00	.00	.00	.00	687.25	688.20	688.13	686.30	685.13	.00	.00	.00	26
27	.00	.00	.00	.00	687.15	688.15	688.10	686.40	684.63	.00	.00	.00	27
28	.00	.00	.00	.00	687.30	688.30	688.35	686.40	684.67	.00	.00	.00	28
29	.00	.00	.00	.00	687.60	688.43	688.55	686.45	684.57	.00	.00	.00	29
30	.00	.00	.00	.00	687.65	688.15	688.30	686.45	684.57	.00	.00	.00	30
31	.00	.00	.00	.00	687.75	.00	688.05	686.37	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	687.75	688.55	688.55	688.47	686.30	685.35	.00	.00	MAX
AVE	.00	.00	.00	.00	685.73	688.14	688.16	687.23	685.55	684.16	.00	.00	AVE
MIN	.00	.00	.00	.00	684.00	687.45	687.87	686.27	684.57	682.15	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	20.	0.	0.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	684.10	684.70	685.93	686.35	684.50	683.23	.00	.00	1
2	.00	.00	.00	.00	684.00	684.50	685.83	686.33	684.30	683.20	.00	.00	2
3	.00	.00	.00	.00	683.90	684.47	685.95	686.37	684.90	682.95	.00	.00	3
4	.00	.00	.00	.00	684.90	684.70	686.40	686.25	684.65	683.00	.00	.00	4
5	.00	.00	.00	.00	683.80	684.15	686.43	686.33	684.55	683.00	.00	.00	5
6	.00	.00	.00	.00	683.73	684.43	686.50	686.43	684.60	682.30	.00	.00	6
7	.00	.00	.00	.00	683.80	684.80	686.60	685.87	684.20	682.25	.00	.00	7
8	.00	.00	.00	.00	684.20	684.90	686.80	685.80	683.50	683.20	.00	.00	8
9	.00	.00	.00	.00	683.95	684.93	686.73	685.45	683.57	683.00	.00	.00	9
10	.00	.00	.00	.00	684.03	684.80	686.83	685.37	683.90	682.75	.00	.00	10
11	.00	.00	.00	.00	684.20	684.75	686.95	686.03	684.35	683.10	.00	.00	11
12	.00	.00	.00	.00	684.10	684.80	686.97	685.70	684.25	682.90	.00	.00	12
13	.00	.00	.00	.00	684.20	685.30	687.00	685.70	683.50	682.70	.00	.00	13
14	.00	.00	.00	.00	684.20	685.00	686.65	685.50	683.35	682.47	.00	.00	14
15	.00	.00	.00	.00	684.00	685.25	686.65	685.50	683.75	682.30	.00	.00	15
16	.00	.00	.00	.00	683.85	686.15	686.73	685.60	683.70	682.15	.00	.00	16
17	.00	.00	.00	.00	683.95	685.05	686.55	685.70	683.85	682.33	.00	.00	17
18	.00	.00	.00	.00	683.97	685.10	686.70	685.60	683.90	682.15	.00	.00	18
19	.00	.00	.00	.00	683.80	685.15	687.20	684.85	683.85	.00	.00	.00	19
20	.00	.00	.00	.00	683.65	685.27	687.00	685.35	683.70	.00	.00	.00	20
21	.00	.00	.00	.00	683.90	685.43	686.83	685.20	683.65	.00	.00	.00	21
22	.00	.00	.00	.00	684.03	685.40	686.55	685.20	683.75	.00	.00	.00	22
23	.00	.00	.00	.00	683.75	685.85	686.77	685.15	683.65	.00	.00	.00	23
24	.00	.00	.00	.00	684.23	685.70	686.77	684.80	683.67	.00	.00	.00	24
25	.00	.00	.00	.00	684.93	685.80	686.20	685.30	683.95	.00	.00	.00	25
26	.00	.00	.00	.00	684.63	685.93	686.25	685.10	683.50	.00	.00	.00	26
27	.00	.00	.00	.00	684.65	685.95	686.25	684.90	683.60	.00	.00	.00	27
28	.00	.00	.00	.00	684.95	686.10	686.35	684.95	683.45	.00	.00	.00	28
29	.00	.00	.00	.00	685.00	686.05	686.40	684.70	683.40	.00	.00	.00	29
30	.00	.00	.00	.00	685.20	686.05	686.33	684.80	683.20	.00	.00	.00	30
31	.00	.00	.00	.00	685.03	.00	686.40	684.45	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	685.20	686.15	687.20	686.43	684.90	683.23	.00	.00	MAX
AVE	.00	.00	.00	.00	684.21	685.22	686.56	685.50	683.89	682.72	.00	.00	AVE
MIN	.00	.00	.00	.00	683.65	684.15	685.83	684.45	683.20	682.15	.00	.00	MIN
NO.	0.	0.	0.	0.	31.	30.	31.	31.	30.	18.	0.	0.	DAY

12 AUG 1970

1953 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1953

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	684.13	685.83	685.80	684.30	683.45	.00	.00	1
2	.00	.00	.00	.00	.00	683.95	685.95	685.70	684.25	683.20	.00	.00	2
3	.00	.00	.00	.00	.00	684.10	685.80	685.53	684.25	683.25	.00	.00	3
4	.00	.00	.00	.00	.00	684.03	686.00	685.30	684.45	683.30	.00	.00	4
5	.00	.00	.00	.00	.00	684.10	685.85	685.25	684.53	683.33	.00	.00	5
6	.00	.00	.00	.00	.00	684.20	685.85	685.00	684.47	683.45	.00	.00	6
7	.00	.00	.00	.00	.00	684.70	685.85	685.05	684.40	683.20	.00	.00	7
8	.00	.00	.00	.00	.00	685.20	685.77	685.15	684.30	683.00	.00	.00	8
9	.00	.00	.00	.00	.00	685.50	685.80	685.35	684.50	683.27	.00	.00	9
10	.00	.00	.00	.00	.00	685.47	685.73	685.30	684.63	683.23	.00	.00	10
11	.00	.00	.00	.00	.00	685.53	685.70	685.00	684.75	683.00	.00	.00	11
12	.00	.00	.00	.00	.00	685.47	685.78	684.97	684.45	682.93	.00	.00	12
13	.00	.00	.00	.00	.00	685.80	685.90	685.00	684.30	682.80	.00	.00	13
14	.00	.00	.00	.00	682.40	686.05	685.87	685.15	683.80	682.98	.00	.00	14
15	.00	.00	.00	.00	682.90	686.00	685.95	685.10	683.73	683.05	.00	.00	15
16	.00	.00	.00	.00	682.87	685.47	685.85	685.05	683.45	682.65	.00	.00	16
17	.00	.00	.00	.00	683.25	685.80	685.70	685.00	683.53	682.60	.00	.00	17
18	.00	.00	.00	.00	683.06	685.25	686.00	685.00	683.75	682.25	.00	.00	18
19	.00	.00	.00	.00	683.25	685.30	685.93	685.10	683.45	682.40	.00	.00	19
20	.00	.00	.00	.00	683.20	685.17	686.00	684.93	683.20	682.30	.00	.00	20
21	.00	.00	.00	.00	682.95	685.27	686.17	684.80	683.15	682.20	.00	.00	21
22	.00	.00	.00	.00	683.27	685.45	686.25	684.65	683.20	682.05	.00	.00	22
23	.00	.00	.00	.00	683.37	685.60	686.15	684.95	683.30	.00	.00	.00	23
24	.00	.00	.00	.00	683.60	685.83	686.10	684.67	683.55	.00	.00	.00	24
25	.00	.00	.00	.00	683.95	685.75	685.85	684.63	683.75	.00	.00	.00	25
26	.00	.00	.00	.00	683.90	685.70	685.80	684.63	683.95	.00	.00	.00	26
27	.00	.00	.00	.00	683.95	685.70	685.77	685.10	683.70	.00	.00	.00	27
28	.00	.00	.00	.00	684.02	685.85	686.00	684.77	683.65	.00	.00	.00	28
29	.00	.00	.00	.00	684.25	685.95	686.15	684.15	683.43	.00	.00	.00	29
30	.00	.00	.00	.00	684.25	685.80	686.10	684.25	683.20	.00	.00	.00	30
31	.00	.00	.00	.00	684.15	.00	685.95	683.55	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	684.25	686.05	686.25	685.80	684.75	683.45	.00	.00	MAX
AVE	.00	.00	.00	.00	683.48	685.27	685.92	684.96	683.91	682.90	.00	.00	AVE
MIN	.00	.00	.00	.00	682.40	683.95	685.70	683.55	683.15	682.05	.00	.00	MIN
NO.	0.	0.	0.	0.	18.	30.	31.	31.	30.	22.	0.	0.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	682.90	.00	.00	.00	.00	.00	.00	.00	15
16	.00	.00	.00	.00	684.45	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	684.80	.00	.00	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	684.80	.00	.00	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	684.40	.00	.00	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	684.20	.00	.00	.00	.00	.00	.00	.00	20
21	.00	.00	.00	.00	684.10	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	684.20	.00	.00	.00	.00	.00	.00	.00	22
23	.00	.00	.00	.00	684.65	.00	.00	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	685.00	.00	.00	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	685.15	.00	.00	.00	.00	.00	.00	.00	25
26	.00	.00	.00	.00	685.20	.00	.00	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	685.20	.00	.00	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	685.25	.00	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	685.30	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	685.75	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	686.05	.00	.00	.00	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	686.05	.00	.00	.00	.00	.00	.00	.00	MAX
AVE	.00	.00	.00	.00	684.79	.00	.00	.00	.00	.00	.00	.00	AVE
MIN	.00	.00	.00	.00	682.90	.00	.00	.00	.00	.00	.00	.00	MIN
NO.	0.	0.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	685.00G	688.10	688.57	686.95	685.00	.00	.00	1
2	.00	.00	.00	.00	.00	685.10G	687.81	688.03	686.30	684.96	.00	.00	2
3	.00	.00	.00	.00	.00	685.10G	687.50	688.23	685.70	684.95	.00	.00	3
4	.00	.00	.00	.00	.00	685.20G	687.37	688.42	686.97	685.00	.00	.00	4
5	.00	.00	.00	.00	.00	685.20G	687.50	688.29	686.40	684.80	.00	.00	5
6	.00	.00	.00	.00	.00	685.30G	687.85	688.33	686.90	684.75	.00	.00	6
7	.00	.00	.00	.00	.00	685.35	689.07	688.29	686.77	684.70	.00	.00	7
8	.00	.00	.00	.00	.00	685.46	687.79	688.25	686.31	684.65	.00	.00	8
9	.00	.00	.00	.00	.00	685.63	687.77	687.85	685.15	684.70	.00	.00	9
10	.00	.00	.00	.00	.00	685.80	687.75	688.05	686.45	684.85	.00	.00	10
11	.00	.00	.00	.00	.00	685.81	687.75	688.15	686.20G	685.10	.00	.00	11
12	.00	.00	.00	.00	.00	685.85	687.85	687.75	685.95	684.65	.00	.00	12
13	.00	.00	.00	.00	.00	685.85	687.87	688.11	685.85	684.25	.00	.00	13
14	.00	.00	.00	.00	.00	685.90	688.00	687.99	686.25	683.05	.00	.00	14
15	.00	.00	.00	.00	.00	685.95	688.30	687.97	687.05	684.00	.00	.00	15
16	.00	.00	.00	.00	.00	686.16	688.29	687.87	687.07	684.15	.00	.00	16
17	.00	.00	.00	.00	.00	686.19	688.25	687.45	687.05	684.04	.00	.00	17
18	.00	.00	.00	.00	.00	686.31	688.50	687.93	686.00	684.23	.00	.00	18
19	.00	.00	.00	.00	.00	686.33	687.57	687.80	685.85	684.15	.00	.00	19
20	.00	.00	.00	.00	.00	686.27	688.55	687.75	685.60	683.95	.00	.00	20
21	.00	.00	.00	.00	.00	686.27	688.19	687.80	685.90	683.75	.00	.00	21
22	.00	.00	.00	.00	.00	686.75	688.05	687.65	685.95	683.25	.00	.00	22
23	.00	.00	.00	.00	.00	686.79	688.31	687.57	685.59	683.80	.00	.00	23
24	.00	.00	.00	.00	.00	687.00	688.85	687.97	685.05	683.87	.00	.00	24
25	.00	.00	.00	.00	.00	686.96	688.70	687.60	685.15	682.81	.00	.00	25
26	.00	.00	.00	.00	.00	687.17	688.99	688.37	684.95	683.60	.00	.00	26
27	.00	.00	.00	.00	.00	686.95	688.65	685.59	685.13	683.65	.00	.00	27
28	.00	.00	.00	.00	.00	686.99	688.40	687.30	685.29	683.75	.00	.00	28
29	.00	.00	.00	.00	.00	687.09	688.49	687.35	685.25	683.37	.00	.00	29
30	.00	.00	.00	.00	.00	687.10	688.43	687.07	685.19	683.99	.00	.00	30
31	.00	.00	.00	.00	.00	.00	688.27	686.95	.00	684.75	.00	.00	31
MAX	.00	.00	.00	.00	.00	687.17	689.07	688.57	687.07	685.10	.00	.00	MAX
AVE	.00	.00	.00	.00	.00	686.09	688.15	687.82	686.01	684.21	.00	.00	AVE
MIN	.00	.00	.00	.00	.00	685.00	687.37	685.59	684.95	682.81	.00	.00	MIN
NO.	0.	0.	0.	0.	0.	30.	31.	31.	30.	31.	0.	0.	DAY

12 AUG 1970

 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.34E	682.53G	680.29	684.63	687.10	686.47	685.13E	684.20G	683.16E	682.82E	1
2	.00	.00	682.28E	682.55E	680.31	685.35	687.03	686.33	685.10G	684.20G	683.19E	682.80G	2
3	.00	.00	682.22E	682.50G	681.18	684.81	686.85	686.45	685.10G	684.20G	683.29E	682.80G	3
4	.00	.00	682.16E	682.50G	683.33	684.69	686.71	686.75	685.13E	684.10G	683.20G	682.80G	4
5	.00	.00	682.20G	682.51E	683.63	684.96	686.65	686.13	685.13E	684.10G	683.17E	682.77E	5
6	.00	.00	682.20G	682.55E	684.23	684.63	686.80	685.83	685.03E	684.10G	683.09E	682.70G	6
7	.00	.00	682.31E	682.49E	684.19	684.27	686.85	686.01	685.03E	684.00G	683.05E	682.71E	7
8	.00	.00	682.32E	682.50E	683.70	684.10	686.80	686.47	684.98E	684.00G	682.99E	682.72E	8
9	.00	.00	682.31E	682.52E	683.48	684.85	686.75	686.35	684.95G	684.00G	683.04E	682.70G	9
10	.00	.00	682.33E	682.52E	683.33	685.00	687.00	686.15	684.93E	683.90G	682.99E	682.60G	10
11	.00	.00	682.33E	682.53E	682.92	685.19	687.07	686.33	684.83E	683.90G	682.90G	682.62E	11
12	.00	.00	682.33E	682.59E	678.97	684.99	687.00	686.35	684.83E	683.90G	682.87E	682.56E	12
13	.00	.00	682.33E	682.59E	678.97	685.35	687.10	685.95	684.78E	683.80G	682.88E	682.60G	13
14	.00	.00	682.33E	682.60G	680.00	685.50	687.25	684.97	684.78E	683.80G	682.95E	682.60E	14
15	.00	.00	682.33E	682.60G	680.23	685.77	686.80	686.20	684.73E	683.80G	682.88E	682.60E	15
16	.00	.00	682.45E	682.60G	680.47	685.85	687.09	686.10	684.65G	683.72E	682.93E	.00	16
17	.00	.00	682.40E	682.59E	682.75	685.97	686.97	685.85	684.58E	683.74E	682.93E	.00	17
18	.00	.00	682.40G	682.59E	683.50	685.80	686.73	686.00	684.58E	683.81E	682.94G	.00	18
19	.00	.00	682.44E	682.61E	683.67	686.07	686.97	685.90	684.48E	683.71E	682.94E	.00	19
20	.00	.00	682.46E	682.65E	683.80	686.33	686.81	686.20	684.48E	683.53E	682.85E	.00	20
21	.00	.00	682.45E	682.65E	684.67	686.00	686.77	685.70	684.43E	683.50G	682.85E	.00	21
22	.00	.00	682.40E	682.65G	684.27	686.41	686.51	685.30	684.47E	683.45E	682.83E	.00	22
23	.00	.00	682.42E	682.65E	684.03	686.57	686.75	685.40	684.50G	683.18E	682.85E	.00	23
24	.00	.00	682.46E	682.69E	683.90	686.33	686.95	685.59	684.40G	683.45E	682.87E	.00	24
25	.00	682.29E	682.45E	682.70E	683.99	686.65	687.07	685.60	684.40G	683.43E	682.86G	.00	25
26	.00	682.26E	682.49E	682.73E	684.81	686.43	686.75	685.43	684.40G	683.40E	682.86E	.00	26
27	.00	682.30E	682.47E	682.84E	683.85	686.40	686.73	685.95	684.30G	683.40E	682.80G	.00	27
28	.00	682.35E	682.46E	682.90G	684.07	686.50	687.10	685.26	684.30G	683.40G	682.72E	.00	28
29	.00	682.23E	682.50G	682.90G	684.53	686.90	687.05	684.95	684.30G	683.35E	682.77G	.00	29
30	.00	.00	682.50G	682.92E	684.47	687.10	686.55	684.70	684.30G	683.28E	682.83E	.00	30
31	.00	.00	682.50G	.00	684.40	.00	686.60	684.95	.00	683.17E	.00	.00	31
MAX	.00	682.35	682.50	682.92	684.81	687.10	687.25	686.75	685.13	684.20	683.29	682.82	MAX
AVE	.00	682.29	682.37	682.62	682.90	685.65	686.88	685.86	684.70	683.73	682.95	682.69	AVE
MIN	.00	682.23	682.16	682.49	678.97	684.10	686.51	684.70	684.30	683.17	682.72	682.56	MIN
NO.	0.	5.	31.	30.	31.	30.	31.	31.	30.	31.	30.	15.	DAY

1957 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1957

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	682.80G	685.63E	686.70G	686.70E	686.80G	685.64E	684.26E	.00	1
2	.00	.00	.00	.00	682.90G	685.70G	686.70E	686.69E	686.80G	685.49E	684.20G	.00	2
3	.00	.00	.00	.00	683.00G	685.82E	686.69E	686.72E	686.84E	685.48E	684.20G	.00	3
4	.00	.00	.00	.00	683.10G	685.94E	686.75E	686.70G	686.80E	685.16E	684.17E	.00	4
5	.00	.00	.00	.00	683.20G	685.97E	686.73E	686.74E	686.71E	684.72E	684.10G	.00	5
6	.00	.00	.00	.00	683.30G	686.07E	686.73E	686.79E	686.78E	685.00G	684.00E	.00	6
7	.00	.00	.00	.00	683.41E	686.12E	686.70G	686.69E	686.88E	685.33E	683.99E	.00	7
8	.00	.00	.00	.00	683.52E	686.22E	686.76E	686.68E	686.80G	685.30E	683.95E	.00	8
9	.00	.00	.00	.00	683.65E	686.30G	686.70E	686.68E	686.84E	685.24E	683.93E	.00	9
10	.00	.00	.00	.00	683.74E	686.33E	686.79E	686.59E	686.72E	685.21E	683.90G	.00	10
11	.00	.00	.00	.00	683.85E	686.37E	686.78E	686.50G	686.64E	685.18E	683.90G	.00	11
12	.00	.00	.00	.00	684.00G	686.33E	686.73E	686.53E	686.63E	685.06E	683.89E	.00	12
13	.00	.00	.00	.00	684.02E	686.38E	686.72E	686.51E	686.64E	684.80G	683.88E	.00	13
14	.00	.00	.00	.00	684.14E	686.43E	686.70G	686.44E	686.42E	684.51E	683.87E	.00	14
15	.00	.00	.00	.00	684.25E	686.53E	686.66E	686.48E	686.40G	684.48E	683.85E	.00	15
16	.00	.00	.00	.00	684.29E	686.60G	686.76E	686.44E	686.42E	684.50G	683.82E	.00	16
17	.00	.00	.00	.00	684.29E	686.67E	686.60E	686.44E	686.42E	684.50G	683.80G	.00	17
18	.00	.00	.00	.00	684.38E	686.61E	686.64E	686.50G	686.44E	684.50G	683.80G	.00	18
19	.00	.00	.00	.00	684.40G	686.72E	686.62E	686.54E	686.22E	684.50G	683.82E	.00	19
20	.00	.00	.00	.00	684.47F	686.74E	686.64E	686.65E	686.22E	684.40G	683.82E	.00	20
21	.00	.00	.00	.00	684.55E	686.74E	686.70G	686.79E	686.20E	684.40G	683.79E	.00	21
22	.00	.00	.00	.00	684.61E	686.69E	686.69E	686.81E	686.10G	684.40G	683.76E	.00	22
23	.00	675.39	.00	.00	684.68E	686.70G	686.57E	686.88E	686.09E	684.40G	683.74E	.00	23
24	.00	.00	.00	.00	684.72E	686.80E	686.84E	686.52E	686.09E	684.30G	683.70G	.00	24
25	.00	.00	.00	.00	684.81E	686.88E	686.79E	686.70G	685.70E	684.30G	683.59E	.00	25
26	.00	.00	.00	.00	685.00G	686.78E	686.69E	686.84E	685.84E	684.30G	683.73E	.00	26
27	.00	.00	.00	.00	685.01E	686.81E	686.59E	686.91E	685.84E	684.30G	683.72E	.00	27
28	.00	.00	.00	.00	685.05F	686.76E	686.70G	686.89E	685.86E	684.32E	683.70G	.00	28
29	.00	.00	.00	.00	685.15E	686.74E	686.79E	686.89E	685.80G	684.44E	683.70G	.00	29
30	.00	.00	.00	.00	685.39E	686.70G	686.73E	686.81E	685.73E	684.29E	683.60G	.00	30
31	.00	.00	.00	.00	685.59E	.00	686.69E	686.81E	.00	684.28E	683.60G	.00	31
MAX	.00	675.39	.00	.00	685.59	686.88	686.84	686.91	686.88	685.64	684.26	.00	MAX
AVE	.00	675.39	.00	.00	684.17	686.44	686.71	686.67	686.39	684.73	683.86	.00	AVE
MIN	.00	675.39	.00	.00	682.80	685.63	686.57	686.44	685.70	684.28	683.59	.00	MIN
NO.	0.	1.	0.	0.	31.	30.	31.	31.	30.	31.	31.	0.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.50G	682.42G	684.80E	687.30G	688.40G	687.50G	685.90G	684.45E	683.40G	682.70G	1
2	.00	.00	682.50G	682.42E	685.08F	687.49E	688.39E	687.40G	685.81E	684.35E	683.30G	682.70G	2
3	.00	.00	682.50G	682.43G	685.15E	687.55E	688.38E	687.30G	685.70G	684.31E	683.31E	682.67E	3
4	.00	.00	682.50G	682.44G	685.20G	687.77E	688.32E	687.25E	685.67E	684.27E	683.30G	.00	4
5	.00	.00	682.50G	682.46G	685.20G	687.86E	688.32E	687.23E	685.65G	684.30G	683.28E	.00	5
6	.00	.00	682.50G	682.48G	685.30G	688.00G	688.30G	687.28E	685.63E	684.20G	683.21E	.00	6
7	.00	.00	682.50G	682.50G	685.37E	688.15E	688.30G	687.25E	685.60G	684.20E	683.20G	.00	7
8	.00	.00	682.50G	682.52G	685.42E	688.20G	688.32E	687.25E	685.51E	684.19E	683.10G	.00	8
9	.00	.00	682.50G	682.53E	685.46E	688.25E	688.34E	687.22E	685.50G	684.10G	683.10G	.00	9
10	.00	.00	682.50G	682.54G	685.55E	688.39E	688.34E	687.10G	685.50G	684.07E	683.09E	.00	10
11	.00	.00	682.49E	682.55G	685.60G	688.46E	688.33E	687.05E	685.47E	684.00G	683.00G	.00	11
12	.00	.00	682.49G	682.56G	685.61E	688.50G	688.28E	687.04E	685.33E	684.00G	683.00G	.00	12
13	.00	.00	682.49G	682.57G	685.79E	688.57E	688.30G	686.85E	685.30G	684.00G	682.91E	.00	13
14	.00	.00	682.49G	682.58G	685.86E	688.60E	688.32E	686.80G	685.20G	683.98E	682.91E	.00	14
15	.00	.00	682.49G	682.60G	685.95E	688.60G	688.30E	686.82E	685.16E	683.96E	683.90G	.00	15
16	.00	.00	682.49G	682.63E	686.04E	688.72E	688.24E	686.78E	685.10G	683.90G	682.90G	.00	16
17	.00	.00	682.49G	682.70G	686.20E	688.70G	688.28E	686.70G	685.00G	683.86E	682.90G	.00	17
18	.00	.00	682.49G	682.80G	686.20G	688.75E	688.20G	686.60G	685.00G	683.84G	682.90E	.00	18
19	.00	.00	682.48E	682.90G	686.30G	688.77E	688.12E	686.53E	684.92E	683.82G	682.89E	.00	19
20	.00	.00	682.48G	683.00G	686.31E	688.80E	688.10G	686.51E	684.91E	683.81E	682.85E	.00	20
21	.00	682.59E	682.48G	683.10G	686.42E	688.80G	688.03E	686.30E	684.90G	683.81E	682.85G	.00	21
22	.00	682.60G	682.47G	683.20G	686.51E	688.70G	688.00G	686.40E	684.81E	683.71E	682.85G	.00	22
23	.00	682.60G	682.47G	683.21E	686.55E	688.70E	688.04E	686.40G	684.80E	683.70G	682.85G	.00	23
24	.00	682.60G	682.46G	683.35E	686.59E	688.75E	687.94E	686.30G	684.72E	683.65G	682.85G	.00	24
25	.00	682.60G	682.46G	683.50G	686.60G	688.71E	687.84E	686.30G	684.70G	683.61E	682.85G	.00	25
26	.00	682.60G	682.45G	683.70G	686.74E	688.67E	687.81E	686.23E	684.70G	683.60G	682.85E	.00	26
27	.00	682.60G	682.45G	683.90G	686.81E	688.60G	687.80G	686.20G	684.66E	683.60E	682.80G	.00	27
28	.00	682.60G	682.444	684.15E	686.82E	688.59E	687.74E	686.12E	684.60G	683.48E	682.80G	.00	28
29	.00	.00	682.44G	684.37E	686.98E	688.60G	687.64E	686.10G	684.52E	683.46E	682.80G	.00	29
30	.00	.00	682.33G	684.62E	687.02E	688.50G	687.62E	686.03E	684.50G	683.40G	682.80G	.00	30
31	.00	.00	682.43G	.00	687.15E	.00	687.58E	686.00G	.00	683.40G	.00	.00	31
MAX	.00	682.60	682.50	684.62	687.15	688.80	688.40	687.50	685.90	684.45	683.90	682.70	MAX
AVE	.00	682.60	682.48	682.96	686.02	688.40	688.13	686.74	685.16	683.90	683.02	682.69	AVE
MIN	.00	682.59	682.33	682.42	684.80	687.30	687.58	686.00	684.50	683.40	682.80	682.67	MIN
NO.	0.	8.	31.	30.	31.	30.	31.	31.	30.	31.	30.	3.	DAY

12 AUG 1970

1959 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1959

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.10G	682.30G	682.80G	684.30G	686.92E	687.37E	686.00G	685.31E	684.70G	684.10E	1
2	.00	.00	682.10G	682.30G	682.80G	684.36E	686.97E	687.35G	685.90G	685.31E	684.72E	684.10G	2
3	.00	.00	682.10G	682.40G	682.80G	684.45E	687.12E	687.32E	685.90G	685.31G	684.72E	684.10G	3
4	.00	.00	682.15E	682.40G	682.80G	684.47E	687.18E	687.30G	685.90G	685.32G	684.70G	684.10G	4
5	.00	.00	682.20G	682.40G	682.80G	684.56E	687.20G	687.20G	685.80G	685.32E	684.67E	684.00G	5
6	.00	.00	682.20G	682.40E	682.89E	684.69E	687.30G	687.17E	685.80G	685.32E	684.65G	684.00G	6
7	.00	.00	682.20G	682.40G	682.90G	684.80G	687.30G	687.12E	685.80G	685.30G	684.62E	684.00G	7
8	.00	.00	682.20G	682.40G	682.90G	684.82E	687.40G	687.10G	685.81E	685.22E	684.60G	684.05E	8
9	.00	.00	682.25E	682.40G	683.00G	684.89E	687.40G	687.10G	685.81E	685.12E	684.60G	684.05E	9
10	.00	.00	682.20G	682.40G	683.10G	684.92E	687.50G	687.07E	685.81E	685.12E	684.60G	684.07E	10
11	.00	.00	682.20G	682.40G	683.14E	684.99E	687.50G	686.97E	685.76E	685.10G	684.60G	684.09E	11
12	.00	.00	682.20G	682.40G	683.20G	685.00G	687.50G	686.97E	685.71E	685.10G	684.50G	684.10G	12
13	.00	.00	682.20G	682.40G	683.20G	685.20G	687.52E	686.92E	685.60G	685.10G	684.50G	684.10G	13
14	.00	682.14E	682.30G	682.41E	683.30G	685.40G	687.60G	686.82E	685.51E	685.10G	684.50G	684.06E	14
15	.00	682.10G	682.30G	682.40G	683.30G	685.69E	687.72E	686.82E	685.61E	685.00G	684.50G	684.09E	15
16	.00	682.10G	682.30G	682.40G	683.40G	685.70G	687.72E	686.70G	685.66E	685.00G	684.40G	684.00G	16
17	.00	682.10G	682.30G	682.40G	683.40G	685.71E	687.70G	686.60G	685.56E	685.00G	684.40G	684.01E	17
18	.00	682.10G	682.33E	682.50G	683.50G	685.80G	687.69E	686.50E	685.51E	685.00G	684.40G	683.99E	18
19	.00	682.10G	682.30G	682.50G	683.50G	685.90E	687.60G	686.50E	685.50G	684.97E	684.40G	683.90E	19
20	.00	682.10G	682.30G	682.50G	683.60G	685.93E	687.62E	686.48E	685.50G	684.92E	684.30G	683.90G	20
21	.00	682.10G	682.30G	682.50G	683.60G	686.00G	687.60G	686.40G	685.50G	684.92E	684.30G	683.93E	21
22	.00	682.10G	682.30G	682.60G	683.70G	686.12E	687.67E	686.32E	685.46E	684.92E	684.30G	683.90E	22
23	.00	682.12E	682.36E	682.59E	683.70G	686.25E	687.67E	686.30G	685.46E	684.82E	684.30G	683.90E	23
24	.00	682.10G	682.30G	682.60G	683.80G	686.32E	687.70G	686.26E	685.41E	684.80E	684.20G	683.85E	24
25	.00	682.10G	682.30G	682.60G	683.80G	686.37E	687.70G	686.17E	685.31E	684.80G	684.20G	683.85G	25
26	.00	682.10G	682.30G	682.70G	683.90G	686.47E	687.70G	686.07E	685.30G	684.80G	684.20G	683.85G	26
27	.00	682.10G	682.30G	682.69E	683.90G	686.50G	687.72E	686.00G	685.40G	684.80G	684.20G	683.85G	27
28	.00	682.10G	682.30G	682.70G	684.00G	686.60G	687.62E	685.82E	685.36E	684.80G	684.10G	683.84E	28
29	.00	.00	682.30G	682.70G	684.00G	686.77E	687.60G	685.94E	685.36E	684.70G	684.10G	683.75E	29
30	.00	.00	682.30G	682.70G	684.10G	685.82E	687.52E	686.00G	685.31E	684.70G	684.10G	683.82E	30
31	.00	.00	682.33E	.00	684.20G	.00	687.52E	685.90G	.00	684.70G	.00	683.76E	31
MAX	.00	682.14	682.36	682.70	684.20	686.82	687.72	687.37	686.00	685.32	684.72	684.10	MAX
AVE	.00	682.10	682.25	682.46	683.39	685.53	687.50	686.66	685.61	685.02	684.44	683.97	AVE
MIN	.00	682.10	682.10	682.30	682.80	684.30	686.92	685.82	685.30	684.70	684.10	683.75	MIN
NO.	0.	15.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.70G	683.04E	682.95E	683.00G	683.93G	685.60	689.34	690.36	689.16	688.30G	687.10E	686.55E	1
2	683.70G	683.01E	682.95G	683.00G	684.15	685.67	689.07	690.18	688.05	688.30G	687.10G	686.55G	2
3	683.70G	683.03E	682.95E	683.00G	684.02E	686.00	689.14	690.08	688.51	688.20G	687.10E	686.55G	3
4	683.66E	683.03E	682.95E	682.95E	684.23	686.50	689.23	690.05	688.73	688.21E	687.00G	686.55G	4
5	683.64E	683.01E	682.95G	683.10E	684.23	686.24	689.23	690.03	689.63	688.21E	686.90G	686.57E	5
6	683.46E	683.00G	682.95G	683.08E	684.25	686.33	689.44	689.99	689.15	688.01E	686.90G	686.55E	6
7	683.54E	683.00G	682.95E	683.10E	684.30	686.94	689.90	689.77	688.81	688.10G	686.80E	686.50G	7
8	683.47E	683.00G	682.90E	683.10G	684.13	685.93	689.38	689.92	688.48	688.10G	686.80G	686.50G	8
9	683.45G	683.00G	682.90E	683.10G	683.74	686.49	688.49	689.84	688.48	688.20G	686.80G	686.40G	9
10	683.43G	683.00E	682.95E	683.10G	683.40	686.98	689.71	690.11	688.72	688.30G	686.80G	686.40G	10
11	683.42E	683.00E	682.95E	683.10E	683.12	686.81	690.21	689.73	688.34	688.34	686.80G	686.30G	11
12	683.41E	682.90E	682.95G	683.10E	683.33	686.64	690.37	689.83	688.83	688.24	686.80G	686.27E	12
13	683.36E	682.90E	682.95G	683.15E	683.39	687.05	690.28	689.66	689.35	687.81E	686.80G	686.27G	13
14	683.35E	683.00G	682.95E	683.08E	683.38	687.24	691.21	689.60	688.90	687.81E	686.80G	686.27E	14
15	683.34E	683.00G	682.97E	683.10G	683.67	687.27	690.55	689.48	687.86	687.80G	686.80G	686.25G	15
16	683.34E	683.00G	682.95E	683.10G	683.64	687.18	690.43	688.95	688.38	687.70G	686.70G	686.25G	16
17	683.30G	683.00G	683.00E	683.20G	684.17	687.24	690.39	689.14	688.99	687.71E	686.70G	686.25G	17
18	683.35E	683.00G	683.05E	683.20E	683.97	687.31	690.09	689.48	688.33	687.71E	686.70G	686.20G	18
19	683.31E	683.00G	683.00G	683.20G	684.36	687.31	690.49	689.35	688.65	687.70G	686.70G	686.20G	19
20	683.26E	683.00G	683.00G	683.25E	684.41	687.68	690.43	689.21	688.82	687.61E	686.70G	686.20G	20
21	683.27E	683.00G	682.95E	683.30E	685.39	687.58	690.27	689.11	688.69E	687.60G	686.70G	686.20G	21
22	683.20G	683.00E	683.00E	683.38E	685.14	687.50	690.38	689.41	688.72	687.60G	686.70G	686.10G	22
23	683.22E	683.00G	683.00G	683.40G	684.43	687.57	690.59	689.39	688.62	687.50G	686.70G	686.10G	23
24	683.20G	683.00E	683.00E	683.40G	684.69	687.59	690.70	687.85	688.37	687.50E	686.70G	686.10G	24
25	683.20G	683.00E	683.05E	683.38E	685.02	687.79	689.76	689.17	688.84	687.40G	686.60G	686.10G	25
26	683.20G	682.95E	683.00G	683.47E	685.22	687.95	690.31	689.25	688.46	687.30G	686.60G	686.10G	26
27	683.20G	682.95E	683.00G	683.50E	685.05	688.03	690.48	688.86	688.49	687.15E	686.60G	686.02E	27
28	683.14E	682.90G	683.00G	683.53E	685.28	689.22	690.08	688.95	688.19	687.10E	686.60G	686.00G	28
29	683.10G	682.90G	683.00G	683.68E	685.20	688.44	690.10	689.11	688.35	687.00G	686.60G	685.97E	29
30	683.10G	.00	683.00G	683.70G	685.93	688.86	690.30	689.07	688.32	687.10G	686.60G	685.90G	30
31	683.10G	.00	683.00G	.00	685.75	.00	690.61	689.07	.00	687.20E	.00	685.90G	31
MAX	683.70	683.04	683.05	683.70	685.93	689.22	691.21	690.36	689.63	688.34	687.10	686.57	MAX
AVE	683.36	682.99	682.97	683.22	684.35	687.16	690.03	689.48	688.64	687.77	686.77	686.26	AVE
MIN	683.10	682.90	682.90	682.95	683.12	685.60	688.49	687.85	687.86	687.00	686.60	685.90	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.90G	685.20G	684.37E	683.50G	683.33E	685.85E	688.30	687.65	686.73	684.76	683.85E	683.60E	1
2	685.90G	685.20G	684.30G	683.50G	683.30G	685.97E	688.17	687.39	686.09	684.63	683.80G	683.55E	2
3	685.87E	685.22E	684.24E	683.46E	683.38E	686.45	688.25	687.68	686.20	684.43	683.80G	683.60E	3
4	685.80G	685.20G	684.20G	683.40G	683.40E	686.87	688.18	687.62	685.85	684.58	683.80G	683.60E	4
5	685.80G	685.10G	684.20G	683.36E	683.40G	686.90	688.35	687.50E	686.33	684.06	683.78E	683.60E	5
6	685.77E	685.12E	684.21E	683.40G	683.50G	687.65	688.30	685.05	685.86	684.52	683.78E	683.55E	6
7	685.77E	685.10G	684.20G	683.30G	683.60G	687.90	688.21	687.13	685.61	684.37	683.70E	683.50E	7
8	685.80G	685.00G	684.17E	683.30G	683.68E	687.25	687.70	687.63	685.87	684.67	683.70E	683.55E	8
9	685.80G	684.90E	684.10G	683.20G	683.80G	687.15	688.05	687.29	685.91	684.53	683.72E	683.50E	9
10	685.61E	684.90G	684.10G	683.22E	683.90G	687.45	687.89	687.51	685.85	683.90	683.95E	683.50E	10
11	685.72E	684.88E	684.11E	683.20G	684.00G	687.57	688.55	687.59	686.15	684.33	683.75E	683.45E	11
12	685.82E	684.90G	684.10G	683.20G	684.13E	688.25	688.45	687.50	685.75	684.07	683.75E	683.45E	12
13	685.80G	684.80G	684.07E	683.21E	684.30G	688.15	688.60	687.17	685.35	683.95	683.72E	683.35E	13
14	685.80G	684.80E	684.00G	683.25G	684.50G	687.55	688.33	687.45	686.45	684.45	683.75E	683.35E	14
15	685.80G	684.70G	684.00G	683.26E	684.63E	687.67	688.31	686.75	685.79	683.93	683.70E	683.30E	15
16	685.70G	684.70G	683.89E	683.20G	684.70G	687.67	688.60	686.80	685.51	683.80	683.70E	683.40E	16
17	685.70G	684.61E	683.90G	683.20E	684.72E	687.79	688.47	686.83	684.75	684.07	683.73E	683.35E	17
18	685.70G	684.60G	683.80G	683.20G	684.75E	687.88	688.60	686.65	685.43	683.79	683.73E	683.30E	18
19	685.60G	684.60G	683.80G	683.20G	684.80G	688.37	688.55	686.88	685.01	684.16	683.68E	683.30E	19
20	685.60G	684.57E	683.77E	683.20G	684.80E	688.35	688.20	686.83	684.85	684.07E	683.67E	683.25E	20
21	685.60G	684.50G	683.80G	683.23E	684.80G	688.15	688.50	686.83	685.27	684.05E	683.65E	683.25E	21
22	685.50G	684.49E	683.70G	683.20G	684.90G	688.22	687.71	686.83	685.17	684.17E	683.65E	683.30E	22
23	685.50G	684.45G	683.70G	683.30G	684.90E	688.32	688.06	686.45	684.51	684.02E	683.65E	683.25E	23
24	685.50G	684.45E	683.70E	683.26E	684.90G	688.13	688.21	686.67	685.93	683.90E	683.65E	683.30E	24
25	685.40G	684.40G	683.60G	683.20G	684.95E	688.13	687.97	686.67	685.74	683.97E	683.70E	683.25E	25
26	685.40G	684.40G	683.60G	683.30G	685.05E	688.27	687.85	686.67	685.97	683.95E	683.60E	683.18E	26
27	685.40G	684.39E	683.64E	683.30E	685.10G	688.80	688.09	686.26	685.01	684.07E	683.65E	683.18E	27
28	685.30G	684.40G	683.60G	683.30G	685.20G	688.35	687.92	686.00	684.99	683.92E	683.65E	683.13E	28
29	685.30G	.00	683.61E	683.30G	685.35E	688.37	687.97	686.17	685.03	684.07E	683.65E	683.18E	29
30	685.20E	.00	683.60G	683.30G	685.55E	688.53	687.80	686.70	684.84	683.87E	683.60E	683.13E	30
31	685.20E	.00	683.50G	.00	685.70G	.00	687.64	686.35	.00	683.82E	.00	683.08E	31
MAX	685.90	685.22	684.37	683.50	685.70	688.80	688.60	687.68	686.73	684.76	683.95	683.60	MAX
AVE	685.64	684.77	683.92	683.28	684.42	687.73	688.19	686.92	685.59	684.16	683.72	683.36	AVE
MIN	685.20	684.39	683.50	683.20	683.30	685.85	687.64	685.05	684.51	683.79	683.60	683.08	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.03E	682.84E	682.92E	683.18E	683.58E	686.53	689.49	691.11	689.16	688.33	686.88E	686.08E	1
2	683.03E	682.89E	682.92E	683.18E	683.68E	686.60	689.20	691.19	689.77	688.33	686.88E	686.03E	2
3	683.08E	682.89E	682.92E	683.18E	684.70G	687.03	687.65	690.87	689.76	689.03	686.78E	685.98E	3
4	683.13E	682.87E	682.92E	683.13E	685.80G	686.83	689.72	690.60	689.63	687.75	686.88E	685.98E	4
5	682.98E	682.86E	682.92E	683.18E	686.61	687.07	690.15	690.60	690.01	688.01	686.83E	685.98E	5
6	683.08E	682.85E	682.96E	683.18E	686.45	687.07	690.37	690.65	690.01	688.31	686.78E	685.98E	6
7	683.08E	682.86E	682.97E	683.18E	686.20	687.17	690.34	690.35	689.52	688.03	686.09	685.93E	7
8	683.03E	682.86E	682.97E	683.18E	686.05	687.11	690.45	690.45	688.84	688.26	686.41	685.88E	8
9	683.03E	682.89E	682.99E	683.18E	686.15	687.27	690.35	690.29	689.49	688.37	686.34	685.88E	9
10	683.03E	682.90E	682.97E	683.18E	685.71	687.24	690.47	690.41	689.74	688.02	686.51	685.81E	10
11	683.03E	682.87E	682.97E	683.23E	685.17	687.80	690.69	690.41	689.75	687.93	686.31	685.81E	11
12	683.03E	682.86E	682.98E	683.18E	685.06	687.20	691.02	690.45	689.31	688.41	686.29	685.76E	12
13	683.03E	682.89E	682.96E	683.18E	685.13	687.45	690.72	690.42	689.11	689.05	686.47	685.76E	13
14	682.98E	682.88E	683.03E	683.18E	685.15	687.47	690.69	690.63	689.27	686.45	686.37	685.76E	14
15	682.98E	682.84E	683.03E	683.23E	685.05	688.27	690.63	690.58	689.28	687.38	686.29	685.76E	15
16	682.93E	682.84E	682.98E	683.28E	685.18	689.00	690.71	690.71	688.61	687.43	686.25	685.76E	16
17	682.98E	682.87E	683.03E	683.23E	685.01	688.35	690.95	691.03	689.11	687.35	686.08	685.71E	17
18	682.88E	682.88E	683.08E	683.18E	685.20	688.40	691.18	690.23	689.16	687.35	686.13	685.66E	18
19	682.93E	682.88E	683.08E	683.23E	685.23	688.45	691.08	690.11	688.97	687.27	686.14	685.66E	19
20	682.93E	682.87E	683.08E	683.28E	685.29	688.41	690.61	690.11	688.77	687.31	686.33E	685.71E	20
21	682.93E	682.87E	683.08E	683.28E	685.20	688.37	690.57	690.09	688.77	687.22	686.28E	685.66E	21
22	682.93E	682.89E	683.13E	683.23E	685.51	688.75	690.57	690.92	688.63	687.12	686.18E	685.61E	22
23	682.98E	682.90E	683.08E	683.28E	685.65	689.25	690.63	690.13	688.69	687.15	686.18E	685.61E	23
24	682.88E	682.91E	683.13E	683.28E	685.77	689.07	690.73	689.63	688.61	686.89	686.18E	685.56E	24
25	682.89E	682.90E	683.13E	683.33E	685.83	689.10	690.53	689.83	688.78	686.97	686.18E	685.61E	25
26	682.90E	682.89E	683.13E	683.33E	686.05	689.33	690.69	689.99	688.59	687.13	686.13E	685.56E	26
27	682.81E	682.89E	683.13E	683.33E	686.10	688.99	690.67	690.11	688.56	686.69	686.08E	685.56E	27
28	682.89E	682.90E	683.13E	683.38E	686.75	689.33	690.73	689.89	688.57	686.20G	686.08E	685.51E	28
29	682.87E	.00	683.13E	683.53E	686.70	689.41	690.61	689.87	688.67	686.85	686.08E	685.46E	29
30	682.84E	.00	683.13E	683.58E	686.50	689.41	690.83	689.81	688.44	687.18	686.13E	685.46E	30
31	682.84E	.00	683.13E	.00	686.42	.00	690.85	689.56	.00	686.85	.00	685.46E	31
MAX	683.13	682.91	683.13	683.58	686.75	689.41	691.18	691.19	690.01	689.05	686.88	686.08	MAX
AVE	682.97	682.88	683.03	683.25	685.58	688.06	690.45	690.36	689.12	687.57	686.35	685.74	AVE
MIN	682.81	682.84	682.92	683.13	683.58	686.53	687.65	689.56	688.44	686.20	686.08	685.46	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1963 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1963

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.41E	684.71E	683.85E	683.13E	685.25	688.34	689.53	688.93	688.55	685.96	685.12E	684.24E	1
2	685.36E	684.66E	683.79E	683.08E	685.32	688.48	689.51	689.00	688.15	686.06	685.19E	684.20E	2
3	685.36E	684.61E	683.79E	683.05E	685.88	688.51	689.46	688.89	688.18	685.78	685.21E	684.22E	3
4	685.41E	684.59E	683.79E	683.04E	686.18	688.62	689.49	688.59	687.88	686.09	685.00E	684.15E	4
5	685.41E	684.59E	683.74E	683.00E	687.02	688.72	689.57	688.69	687.57	686.03	684.98E	684.22E	5
6	685.31E	684.54E	683.69E	683.06E	688.15	688.71	689.42	688.75	687.19	685.86	685.01E	684.17E	6
7	685.31E	684.59E	683.68E	683.01E	687.46	688.80	689.36	688.77	687.13	685.88	684.86E	684.14E	7
8	685.36E	684.44E	683.63E	682.97E	686.72	688.78	690.01	688.75	687.28	685.72	684.80E	684.10E	8
9	685.31E	684.44E	683.58E	682.98E	686.49	689.24	689.49	688.93	687.36	685.74	684.78E	684.08E	9
10	685.26E	684.43E	683.63E	682.99E	686.40	689.16	689.29	688.83	687.33	685.81	684.75E	684.03E	10
11	685.16E	684.43E	683.57E	683.00E	686.46	689.07	689.73	688.67	686.93	686.03	684.71E	684.06E	11
12	685.21E	684.28E	683.57E	682.95E	686.65	689.11	689.49	688.63	686.81	685.62	684.63E	684.02E	12
13	685.16E	684.28E	683.52E	683.01E	686.70	688.81	689.37	688.79	687.45	685.70	684.77E	683.97E	13
14	685.21E	684.23E	683.47E	682.97E	686.76	688.83	689.21	688.41	687.45	685.70	684.61E	683.96E	14
15	685.16E	684.27E	683.47E	682.97E	686.86	688.95	689.20	688.37	687.11	685.66	684.48E	683.96E	15
16	685.11E	684.22E	683.41E	682.93E	686.94	689.21	689.11	688.23	686.78	685.57	684.67E	683.95E	16
17	685.06E	684.17E	683.46E	682.94E	687.09	689.37	689.39	688.29	686.67	685.67	684.59E	683.90E	17
18	685.01E	684.17E	683.46E	682.95E	686.96	689.13	689.11	688.25	686.69	685.78	684.56E	683.89E	18
19	685.11E	684.12E	683.36E	682.96E	687.26	689.25	689.10	688.25	686.65	685.54	684.57E	683.87E	19
20	684.96E	684.01E	683.36E	682.91E	687.49	688.86	689.00	688.13	686.67	685.52	684.50E	683.85E	20
21	684.91E	684.06E	683.35E	682.92E	687.43	689.31	689.31	688.59	686.55	685.16	684.41E	683.83E	21
22	684.91E	684.01E	683.40E	682.93E	687.48	689.66	689.23	688.35	686.68	685.12	684.33E	683.78E	22
23	684.91E	683.96E	683.35E	682.98E	687.56	689.45	688.77	688.18	686.44	685.63	684.31E	683.76E	23
24	684.91E	684.01E	683.35E	683.04E	687.67	689.38	688.92	687.95	686.69	685.34	684.42E	683.75E	24
25	684.91E	683.96E	683.30E	683.05E	687.66	688.91	689.03	687.97	686.62	685.38	684.36E	683.73E	25
26	684.81E	683.90E	683.29E	683.11E	687.52	689.21	689.18	687.93	686.56	685.19	684.38E	683.72E	26
27	684.86E	683.90E	683.29E	683.22E	687.70	689.37	688.99	687.87	686.43	685.15	684.39E	683.70E	27
28	684.81E	683.90E	683.24E	683.27E	687.74	689.50	689.07	687.81	686.32	684.99	684.30G	683.68E	28
29	684.86E	.00	683.24E	683.43E	688.06	689.59	689.03	687.81	686.52	685.10G	684.29E	683.67E	29
30	684.81E	.00	683.14E	683.69E	687.44	689.65	689.15	687.59	686.12	685.24	684.31E	683.66E	30
31	684.76E	.00	683.13E	.00	686.34	.00	689.01	687.59	.00	685.28	.00	683.65E	31
MAX	685.41	684.71	683.85	683.69	688.34	689.66	690.01	689.00	688.55	686.09	685.21	684.24	MAX
AVE	685.10	684.27	683.43	683.05	687.05	689.07	689.28	688.38	687.03	685.59	684.64	683.93	AVE
MIN	684.76	683.90	683.13	682.91	685.25	688.34	688.77	687.59	686.12	684.99	684.29	683.65	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.62E	683.29E	683.00E	682.94E	683.36E	685.97	689.92	690.42	690.20	688.71	687.11	686.43E	1
2	683.60E	683.27E	683.00E	682.93E	683.38E	686.40	690.04	690.14	690.26	688.84	687.62	686.43E	2
3	683.58E	683.28E	682.97E	682.92E	682.93	686.17	690.17	690.08	690.02	688.54	687.66	686.45E	3
4	683.60G	683.23E	682.94E	682.97E	683.09	686.53	690.14	690.29	689.81	688.57	687.71	686.46E	4
5	683.60G	683.23E	682.92E	683.00E	683.27	686.77	690.26	690.89	690.18	688.63	687.12	686.44E	5
6	683.60G	683.25E	682.91E	682.96E	683.93	686.37	690.22	689.89	690.26	688.57	686.83	686.41E	6
7	683.60G	683.27E	682.90E	682.97E	684.42	686.43	690.26	690.30	689.76	688.62	686.88	686.41E	7
8	683.50G	683.25E	682.89E	682.98E	684.29	686.73	690.44	690.46	689.77	688.61	687.15	686.40E	8
9	683.50G	683.23E	682.88E	682.95E	684.71	686.91	690.44	690.49	689.68	688.64	687.24	686.37E	9
10	683.50G	683.22E	682.90G	682.96E	684.43	687.05	690.12	690.55	689.16	688.37	687.36	686.37E	10
11	683.50G	683.22E	682.90G	683.01E	684.51	687.52	690.17	690.66	689.29	688.63	687.32	686.33E	11
12	683.40G	683.18E	682.90G	683.02E	684.45	687.50	690.34	690.68	689.70	688.64	687.25	686.31E	12
13	683.40G	683.18E	682.90G	683.02E	684.32	687.56	690.14	690.74	689.42	688.82	687.12	686.29E	13
14	683.40G	683.14E	682.90G	683.01E	684.47	688.40	690.30	690.60	689.54	688.25	686.91	686.29E	14
15	683.40G	683.12E	682.90G	683.04E	684.45	687.90	690.74	690.55	689.38	688.27	686.80	686.25E	15
16	683.38E	683.12E	682.90G	683.05E	684.69	687.96	690.51	690.70	689.27	688.02	686.04	686.24E	16
17	683.36E	683.13E	682.90G	683.07E	684.94	688.29	690.33	690.76	689.30	687.99	686.71	686.20E	17
18	683.34E	683.11E	682.93E	683.10E	684.85	687.90	690.07	690.80	689.22	688.36	686.81E	686.17E	18
19	683.32E	683.10E	682.90E	683.11E	684.89	688.55	690.23	690.62	689.20	687.94	686.77E	686.14E	19
20	683.39E	683.06E	682.94E	683.14E	684.91	688.55	690.07	690.63	689.08	687.87	686.78E	686.10E	20
21	683.43E	683.09E	682.94G	683.07E	684.95	688.65	690.28	690.46	688.94	687.99	686.76E	686.03E	21
22	683.42E	683.07E	682.94E	683.13E	685.00	688.90	690.08	690.50	689.18	688.02	686.74E	686.06E	22
23	683.40E	683.09E	682.92E	683.17E	685.40	689.47	689.73	690.50	689.00	688.01	686.67E	686.06E	23
24	683.41E	683.08E	682.94E	683.14E	685.30	689.25	690.07	690.38	689.02	688.13	686.62E	686.02E	24
25	683.41E	683.06E	682.90E	683.16E	685.17	689.55	690.12	691.40	689.23	687.75	686.64E	685.98E	25
26	683.41E	683.05E	682.92E	683.20E	685.37	689.57	690.19	690.59	688.60	688.03	686.60E	685.96E	26
27	683.44E	683.03E	682.90E	683.25E	685.88	690.06	690.42	690.60	689.05	687.80	686.55E	685.91E	27
28	683.41E	682.99E	682.88E	683.28E	685.12	689.17E	690.25	690.50	689.05	686.76	686.51E	685.91E	28
29	683.37E	683.01E	682.94E	683.25E	685.90	689.59	690.32	690.28	688.84	687.32	686.51E	685.88E	29
30	683.36E	.00	682.94G	683.31E	685.93	689.86	690.45	690.28	688.79	687.16	686.51E	685.85E	30
31	683.33E	.00	682.95E	.00	685.87	.00	690.68	690.11	.00	687.79	.00	685.79E	31
MAX	683.62	683.29	683.00	683.31	685.93	690.06	690.74	691.40	690.26	688.84	687.71	686.48	MAX
AVE	683.45	683.15	682.92	683.07	684.65	687.98	690.24	690.51	689.41	688.18	686.91	686.19	AVF
MIN	683.32	682.99	682.88	682.92	682.93	685.97	689.73	689.89	688.60	686.76	686.04	685.79	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1965	LAKE ATHABASCA AT FORT CHIPEWYAN	07MD001	1965

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.76E	684.80E	684.12E	683.51E	683.99E	687.04	689.74	690.83	688.97	688.38	686.08	685.74E	1
2	685.75E	684.77E	684.05E	683.54E	684.80G	687.23	689.80	690.79	688.95	687.62	686.46	685.75E	2
3	685.73E	684.73E	684.05E	683.55E	685.60G	687.20	690.30	690.65	688.90	687.88	686.49E	685.73E	3
4	685.71E	684.67E	684.01E	683.54E	686.34	687.44	690.05	690.53	688.93	687.64	686.45E	685.74E	4
5	685.67E	684.66E	683.97E	683.57E	686.86	687.47	689.98	690.55	688.85	687.74	686.42E	685.70E	5
6	685.63E	684.61E	683.95E	683.57E	687.81	686.94	690.06	690.27	688.73	687.60	686.46E	685.72E	6
7	685.61E	684.60E	683.91E	683.55E	687.73	687.54	690.33	690.35	688.85	687.34	686.42E	685.69E	7
8	685.61E	684.62E	683.87E	683.56E	686.31	687.95	690.64	690.33	689.09	687.53	686.41E	685.68E	8
9	685.59E	684.62E	683.80E	683.59E	685.61	688.58	690.54	690.08	688.54	686.70	686.36E	685.65E	9
10	685.54E	684.60E	683.79E	683.59E	685.90	688.47	690.69	690.04	688.58	687.40	686.35E	685.64E	10
11	685.50E	684.57E	683.78E	683.58E	686.04	688.84	690.58	690.02	688.49	687.60	686.25E	685.61E	11
12	685.47E	684.59E	683.78E	683.56E	686.32	688.93	690.70	689.70	688.59	687.28	686.17E	685.61E	12
13	685.39E	684.60E	683.75E	683.56E	685.94	688.62	690.60	690.11	688.51	687.20	686.18E	685.60E	13
14	685.37E	684.58E	683.72E	683.55E	686.24	688.62	690.98	689.60	688.64	687.70	686.18E	685.54E	14
15	685.36E	684.55E	683.70E	683.57E	686.66	689.32	691.33	690.11	688.47	687.66	686.16E	685.50E	15
16	685.31E	684.52E	683.66E	683.56E	686.92	689.36	691.12	689.95	688.33	686.74	686.11E	685.51E	16
17	685.26E	684.51E	683.64E	683.56E	687.07	689.52	690.90	689.86	688.44	686.40	686.07E	685.49E	17
18	685.27E	684.46E	683.59E	683.57E	686.62	689.22	690.51	689.68	688.39	687.00	686.03E	685.47E	18
19	685.18E	684.42E	683.56E	683.58E	686.60	689.20	689.74	689.75	688.21	686.32	686.01E	685.48E	19
20	685.17E	684.42E	683.50E	683.56E	686.52	689.46	690.41	689.77	688.27	687.30	685.94E	685.46E	20
21	685.11E	684.38E	683.48E	683.58E	686.63	689.55	689.92	689.72	688.14	686.77	685.89E	685.42E	21
22	685.06E	684.31E	683.48E	683.58E	686.69	689.57	691.67	689.57	688.02	686.92	685.86E	685.40E	22
23	685.06E	684.26E	683.48E	683.61E	686.73	689.70	691.07	689.89	687.73	686.92	685.86E	685.38E	23
24	685.05E	684.23E	683.43E	683.63E	687.23	689.96	690.87	690.63	688.38	686.09	685.84E	685.38E	24
25	685.02E	684.19E	683.49E	683.66E	686.99	689.76	691.16	689.81	688.04	686.45	685.84E	685.37E	25
26	684.98E	684.24E	683.49E	683.69E	686.99	690.14	691.21	689.54	688.12	686.36	685.81E	685.35E	26
27	684.95E	684.22E	683.50E	683.74E	686.79	690.56	691.19	689.57	687.68	686.76	685.78E	685.31E	27
28	684.90E	684.19E	683.51E	683.83E	686.85	690.02	690.88	689.63	687.70	686.48	685.77E	685.27E	28
29	684.87E	.00	683.50E	683.90E	687.10	689.73	690.84	689.44	687.64	686.60	685.77E	685.24E	29
30	684.85E	.00	683.50E	683.96E	687.31	689.46	691.24	689.19	688.70	686.67	685.73E	685.22E	30
31	684.83E	.00	683.53E	.00	687.16	.00	690.86	689.08	.00	686.74	.00	685.19E	31
MAX	685.76	684.80	684.12	683.96	687.81	690.56	691.67	690.83	689.09	688.38	686.49	685.75	MAX
AVE	685.31	684.50	683.70	683.61	686.53	688.85	690.64	689.97	688.43	687.09	686.10	685.51	AVE
MIN	684.83	684.19	683.43	683.51	683.99	686.94	689.74	689.08	687.64	686.09	685.73	685.19	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1966 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1966

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.19E	684.34E	683.60E	682.76E	683.17E	686.45	688.38	688.80	686.03	687.47	685.75	685.23E	1
2	685.17E	684.28E	683.55E	682.77E	683.21E	686.33	688.72	688.59	688.14	687.30	685.34	685.20E	2
3	685.13E	684.23E	683.47E	682.76E	683.25E	686.19	688.52	688.59	688.06	686.99	685.44	685.15E	3
4	685.09E	684.21E	683.43E	682.73E	683.33E	686.62	688.60	688.86	688.31	687.13	685.80E	685.14E	4
5	685.08E	684.19E	683.39E	682.73E	683.34E	686.90	688.47	689.15	688.21	686.69	685.75E	685.10E	5
6	685.03E	684.17E	683.36E	682.74E	683.38E	686.70	688.54	689.00	688.13	687.32	685.80E	685.09E	6
7	685.02E	684.14E	683.32E	682.75E	683.43E	686.64	688.51	688.74	687.93	687.02	685.76E	685.06E	7
8	684.98E	684.13E	683.30E	682.73E	683.49E	686.73	688.46	688.49	688.21	686.52	685.75E	685.04E	8
9	684.96E	684.12E	683.26E	682.73E	683.61E	686.73	688.59	688.17	688.22	686.79	685.70E	684.99E	9
10	684.92E	684.10E	683.23E	682.70E	683.75E	686.82	688.62	688.67	687.90	686.79	685.71E	684.98E	10
11	684.91E	684.13E	683.25E	682.71E	684.49	686.93	688.66	688.55	688.13	686.92	685.69E	684.96E	11
12	684.91E	684.08E	683.23E	682.72E	684.04E	686.97	688.41	688.38	687.53	686.70	685.66E	684.90E	12
13	684.85E	684.08E	683.17E	682.75E	684.13E	686.88	688.62	688.36	688.00	686.65	685.66E	684.89E	13
14	684.83E	684.07E	683.12E	682.76E	684.15	687.14	688.70	688.52	687.89	686.15	685.63E	684.88E	14
15	684.82E	684.04E	683.10E	682.77E	684.46	687.19	688.70	688.58	688.34	686.25	685.59E	684.84E	15
16	684.80E	683.99E	683.10E	682.83E	684.51	687.24	688.50	688.76	688.19	686.44	685.58E	684.81E	16
17	684.60E	683.97E	683.07E	682.84E	684.65	687.81	688.74	688.64	687.87	686.59	685.59E	684.80E	17
18	684.80E	683.90E	683.05E	682.87E	684.86	687.54	689.00	688.73	687.93	686.61	685.57E	684.77E	18
19	684.78E	683.86E	683.03E	682.89E	685.06	687.58	688.50	688.58	687.50	686.07	685.53E	684.76E	19
20	684.73E	683.82E	683.05E	682.90E	685.00	687.80	688.47	688.61	686.57	686.96	685.51E	684.71E	20
21	684.71E	683.82E	683.02E	682.92E	685.24	687.37	688.52	688.48	687.41	686.66	685.53E	684.69E	21
22	684.67E	683.79E	683.01E	682.98E	685.25	687.91	689.09	688.35	687.50	685.94	685.50E	684.66E	22
23	684.64E	683.76E	682.93E	682.99E	685.39	688.11	688.68	688.18	687.60	686.45	685.45E	684.63E	23
24	684.59E	683.73E	682.90E	682.97E	685.14	687.96	688.86	688.51	687.66	685.60	685.39E	684.60E	24
25	684.60E	683.71E	682.88E	682.98E	685.58	688.23	689.00	688.31	687.62	685.17	685.45E	684.59E	25
26	684.58E	683.68E	682.85E	682.98E	686.29	688.18	688.85	688.44	687.47	686.01	685.37E	684.59E	26
27	684.52E	683.66E	682.86E	683.02E	685.85	688.10	688.80	688.80	687.77	685.90	685.36E	684.52E	27
28	684.46E	683.64E	682.84E	683.06E	685.80	688.91	688.92	688.71	687.46	685.92	685.33E	684.51E	28
29	684.42E	.00	682.80E	683.10E	686.14	687.86	689.30	688.29	688.02	685.94	685.32E	684.47E	29
30	684.40E	.00	682.81E	683.12E	685.88	687.93	688.82	688.45	687.15	685.72	685.28E	684.41E	30
31	684.36E	.00	682.81E	.00	686.04	.00	688.86	687.94	.00	685.78	.00	684.41E	31
MAX	685.19	684.34	683.60	683.12	686.29	688.91	689.30	689.15	688.34	687.47	685.80	685.23	MAX
AVE	684.60	683.99	683.12	682.85	684.58	687.32	688.69	688.56	687.82	686.47	685.56	684.82	AVE
MIN	684.36	683.64	682.80	682.70	683.17	686.19	688.38	687.94	686.57	685.17	685.28	684.41	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1967						LAKE ATHABASCA AT FORT CHIPEWYAN			07MD001			1967

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	684.42E	683.66E	683.10G	682.90G	683.20G	686.85	690.69	689.97	688.42	687.74	684.91	684.40G	1
2	684.38E	683.63E	683.00G	682.90G	683.30G	687.05	690.55	689.82	687.96	686.80	684.91	684.40G	2
3	684.34E	683.60E	683.00G	682.90G	683.50G	687.35	690.57	689.74	688.06	686.87	685.01	684.30G	3
4	684.33E	683.57E	683.00G	682.90G	683.70G	687.50	690.55	689.62	688.46	686.37	684.96	684.30G	4
5	684.30E	683.55E	683.00G	682.90G	684.00G	687.55	690.55	689.79	688.36	686.40	684.90G	684.30G	5
6	684.27E	683.54E	683.00G	682.90G	684.30G	687.70	690.90	689.63	687.98	686.30	684.90G	684.30G	6
7	684.25E	683.50E	683.00G	682.90G	684.70G	687.65	690.78	689.77	687.98	686.24	684.90G	684.30G	7
8	684.24E	683.45E	683.00G	682.90G	685.00G	688.05	690.97	689.60	688.08	686.16	684.90G	684.30G	8
9	684.21E	683.40G	683.02E	682.90G	685.30G	688.35	690.89	689.56	688.03	686.04	684.80G	684.20G	9
10	684.18E	683.40G	683.00G	682.90G	685.70G	688.55	690.79	689.81	687.43	688.20	684.80G	684.20G	10
11	684.19E	683.40G	683.00G	682.90G	686.10G	688.65	690.75	689.25	688.23	685.64	684.80G	684.20G	11
12	684.19E	683.40G	683.00G	682.90G	686.30G	688.65	690.71	689.22	687.58	686.00	684.80G	684.20G	12
13	684.17E	683.40G	683.00G	682.90G	686.50G	688.90	690.55	689.39	687.51	685.61	684.80G	684.10G	13
14	684.15E	683.30G	683.00G	682.87E	686.70	688.85	690.95	689.37	687.38	685.61	684.70G	684.10G	14
15	684.11E	683.30G	683.00G	682.90G	686.95	689.64	690.49	689.55	687.51	685.72	684.70G	684.10G	15
16	684.08E	683.30G	683.00G	682.90G	686.00	689.74	690.52	689.34	687.38	685.78	684.73G	684.10G	16
17	684.05E	683.30G	683.00G	682.90G	685.05	689.59	690.49	688.90	688.23	685.56	684.70G	684.10G	17
18	684.03E	683.30G	683.00G	682.90G	684.85	689.38	690.24	689.14	687.35	686.21	684.60G	684.07E	18
19	683.98E	683.30G	683.00G	682.80G	685.30	689.48	690.14	689.50	685.23	685.56	684.60G	684.00G	19
20	683.95E	683.20G	682.90G	682.80G	685.20	689.63	690.13	689.00	687.01	685.49	684.60G	684.00G	20
21	683.95E	683.20G	682.90G	682.70G	685.20	689.82	690.22	689.07	686.98	685.86	684.60G	684.00G	21
22	683.94E	683.20G	682.90G	682.70G	685.50	689.82	690.21	688.73	686.93	685.97	684.60G	684.00G	22
23	683.91E	683.20G	682.90G	682.80G	685.60	689.92	690.11	689.06	686.95	685.73	684.50G	683.90G	23
24	683.88E	683.20G	682.90G	682.80G	685.95	689.96	688.58	688.44	686.98	685.46	684.50G	683.90G	24
25	683.86E	683.20G	682.90G	682.90G	685.95	690.13	689.95	688.16	686.37	685.56	684.50G	683.90G	25
26	683.83E	683.10G	682.90G	682.90G	686.05	690.25	690.16	688.36	686.30	685.19	684.50G	683.90G	26
27	683.79E	683.10G	682.90G	683.00G	686.40	690.58	690.14	688.26	686.80	685.21	684.50G	683.90G	27
28	683.76E	683.10G	682.90G	683.00G	686.65	690.51	690.46	688.49	686.40	685.19	684.50G	683.90G	28
29	683.73E	.00	682.90G	683.10G	686.75	690.06	690.16	688.62	686.54	684.98	684.40G	683.80G	29
30	683.71E	.00	682.90G	683.10G	686.65	690.56	690.04	688.42	687.64	684.96	684.40G	683.80G	30
31	683.69E	.00	.00	.00	686.75	.00	689.82	688.62	.00	684.91	684.40G	683.80G	31
MAX	684.42	683.66	683.10	683.10	686.95	690.58	690.97	689.97	688.46	688.20	685.01	684.40	MAX
AVE	684.06	683.35	682.97	682.89	685.45	689.02	690.39	689.17	687.40	685.91	684.69	684.09	AVE
MIN	683.69	683.10	682.90	682.70	683.20	686.85	688.58	688.16	685.23	684.91	684.40	683.80	MIN
NO.	31.	28.	30.	30.	31.	30.	31.	31.	30.	31.	31.	31.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.80G	683.20G	682.85G	682.86G	683.19E	684.35	684.50	684.66	683.72	682.83	681.70	682.61E	1
2	683.70G	683.20G	682.85G	682.87E	683.23E	685.15	684.52	684.29	684.53	682.83	681.80	682.58E	2
3	683.70G	683.20G	682.85G	682.88G	683.29E	683.93	684.38	684.62	683.60	682.97	682.59E	682.62E	3
4	683.70G	683.20G	682.85G	682.89G	683.32E	683.91	684.96	684.57	683.21	682.88	682.67E	682.58E	4
5	683.70G	683.20G	682.85G	682.90G	683.41E	684.15	685.25	684.50	683.19	682.61	682.56E	682.55E	5
6	683.70G	683.20G	682.85G	682.91G	683.45E	684.28	685.00	684.37	683.63	683.02	682.59E	682.34	6
7	683.60G	683.20G	682.85G	682.92G	683.52E	684.14	684.91	684.06	683.55	682.96	682.58E	682.46	7
8	683.60G	683.10G	682.85G	682.93G	683.58E	684.07	684.64	684.25	683.53	683.09	682.60E	682.23	8
9	683.60G	683.10G	682.85G	682.94G	683.60E	684.04	684.70	684.19	683.32	683.05	682.65E	682.17	9
10	683.60G	683.10G	682.85G	682.95G	683.61E	684.87	684.99	683.78	683.39	683.08	682.59E	682.22	10
11	683.60G	683.10G	682.85G	682.96G	683.65E	684.45	685.01	684.44	683.23	682.83	682.59E	682.19	11
12	683.50G	683.10G	682.85G	682.97G	683.69E	684.69	685.21	684.71	683.37	683.21	682.56E	682.07	12
13	683.50G	683.10G	682.85G	682.97G	683.70E	683.83	684.19	684.00	682.59	682.81	682.62E	682.12	13
14	683.50G	683.10G	682.85G	682.98G	683.71E	684.05	684.88	683.96	683.19	682.65	682.64E	682.10	14
15	683.50G	683.00G	682.85G	682.98G	683.70E	683.87	684.99	684.38	683.68	682.76	682.58E	682.00	15
16	683.50G	683.00G	682.85G	682.99G	683.73E	683.87	684.83	684.23	683.13	682.39	682.56E	682.03	16
17	683.45G	683.00G	682.85G	682.99G	683.74E	684.30	684.84	684.19	683.65	682.60	682.56E	681.96	17
18	683.40G	683.00G	682.85G	682.99E	683.74E	684.52	684.80	684.41	683.68	683.37	682.59E	682.50E	18
19	683.40G	683.00G	682.85G	683.01E	683.74E	684.63	684.68	684.51	683.23	682.58	682.64E	682.52E	19
20	683.40G	683.00G	682.85G	683.02E	683.75E	685.24	684.82	684.03	683.31	682.65	682.68E	682.49E	20
21	683.40G	683.00G	682.85G	683.04E	683.75E	684.62	684.82	684.04	683.61	682.83	682.65E	682.50E	21
22	683.40G	682.90G	682.85G	683.04E	685.20	685.28	684.71	684.11	683.85	682.90	682.68E	682.47E	22
23	683.40G	682.90G	682.85G	683.02E	684.20	684.88	684.82	684.07	682.81	682.59	682.67E	682.43E	23
24	683.40G	682.90G	682.85G	683.00E	683.75E	685.11	684.52	684.04	683.02	682.37	682.62E	682.41E	24
25	683.30G	682.90G	682.85G	683.03E	683.76E	683.98	684.54	683.92	682.69	682.60	682.65E	682.41E	25
26	683.30G	682.90G	682.85G	683.02E	683.78E	684.13	684.41	683.81	682.77	682.68	682.69E	682.42E	26
27	683.30G	682.90G	682.85G	683.05E	683.79E	684.50	684.90	683.66	683.07	682.68	682.58E	682.41E	27
28	683.30G	682.90G	682.85G	683.08E	684.02	685.05	684.91	683.92	682.63	682.72	682.64E	682.37E	28
29	683.30G	682.84E	682.85G	683.11E	684.10	684.87	684.95	683.86	682.52	682.75	682.69E	682.38E	29
30	683.30G	.00	682.85G	683.14E	684.11	684.61	684.59	683.67	682.58	681.90	682.70E	682.37E	30
31	683.30G	.00	682.85G	.00	684.11	.00	684.31	683.85	.00	681.70	.00	682.41E	31
MAX	683.80	683.20	682.85	683.14	685.20	685.28	685.25	684.71	684.53	683.37	682.70	682.62	MAX
AVE	683.49	683.04	682.85	682.98	683.74	684.45	684.76	684.16	683.28	682.74	682.56	682.35	AVE
MIN	683.30	682.84	682.85	682.86	683.19	683.83	684.19	683.66	682.52	681.70	681.70	681.96	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1969 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1969

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	682.20G	678.10G	676.30G	676.70	685.20G	685.77	684.97	684.13E	683.41	682.68	682.05E	681.07	1
2	682.00G	678.00G	676.30G	676.65	685.22G	685.63	685.05	684.11E	684.08	682.76	682.03E	681.18	2
3	681.80G	677.90G	676.30G	676.65	685.25G	685.68	685.75	684.04E	684.33	682.56	682.01G	681.34	3
4	681.60G	677.80G	676.30G	676.49	685.28G	685.79	685.71	683.99E	685.70	682.51	682.00E	681.20	4
5	681.40G	677.70G	676.30G	676.32	685.30G	685.74	685.30	683.95E	685.45	682.35	682.00G	681.12	5
6	681.20G	677.60G	676.30G	676.40	685.33G	685.94	685.01	683.90E	683.58	682.57	681.99G	681.26	6
7	681.00G	677.50G	676.30G	676.51	685.36G	685.60	684.89	683.84E	682.83	682.60	681.99G	681.31	7
8	680.80G	677.40G	676.20G	676.23	685.40G	685.62	684.94	683.78E	682.74	682.93	681.99G	681.34	8
9	680.60G	677.30G	676.20G	676.25	685.44G	686.16	684.80	683.78E	682.97	683.24	681.98E	681.33	9
10	680.40G	677.20G	676.20G	676.36	685.47G	686.15	684.98	683.76E	682.86	682.71	682.00E	681.34	10
11	680.20G	677.10G	676.20G	676.27	685.50G	685.91	684.84	683.74E	682.76	682.33	682.00G	681.35	11
12	680.10G	677.00G	676.20G	676.42	685.55G	685.68	684.19	683.71E	683.91	681.95	681.99G	681.36	12
13	680.03	676.90G	676.20G	676.86	685.60G	685.66	684.20	683.69E	685.06	682.18	681.98G	681.38	13
14	679.91	676.90G	676.20G	676.84	685.70G	685.56	684.24	684.06	684.03	682.54	681.97E	681.43	14
15	679.80G	679.60G	676.10G	677.00	685.80G	685.30	684.35	683.94	683.24	681.94	681.91E	681.30	15
16	679.70G	679.80G	676.10G	677.77	685.85	685.75	684.63	683.70	682.68	682.18	681.90E	681.18	16
17	679.60G	676.73	676.10	678.56	685.94	685.50	684.83	683.89	682.70	681.94	681.90G	681.13	17
18	679.50G	676.60G	676.10G	678.99	686.10	685.90	684.81	683.93	683.29	682.16	681.91E	681.03	18
19	679.40G	676.47	676.16	680.04	685.82	685.43	684.69	683.77	683.38	682.08	681.91E	681.00	19
20	679.30G	676.40G	676.25	680.93	685.83	685.09	684.71	683.40	682.69	682.23	681.90G	680.95	20
21	679.20G	676.40G	676.38	682.43	685.88	685.48	684.51E	683.11	682.80	681.85	681.89E	680.91	21
22	679.10G	676.40G	676.41	683.83	685.82	685.82	684.51E	681.89	682.73	682.19	681.90G	680.77	22
23	679.00G	676.40G	676.17	685.03	685.95	685.53	684.50E	683.06	682.68	681.69	681.90E	680.73	23
24	678.90G	676.40G	676.40	684.92	686.13	685.38	684.41E	684.20	682.71	681.20	681.92E	680.56	24
25	678.80G	676.40G	676.53	685.13	685.86	685.44	684.38E	684.33	682.69	681.71G	681.93G	680.48	25
26	678.70G	676.40G	676.05	685.24	685.94	685.28	684.36E	682.35	682.62	682.22E	681.94G	680.31	26
27	678.60G	676.40G	676.55	685.26	685.97	685.27	684.36E	683.53	682.57	682.17E	680.95	680.26	27
28	678.50G	676.40G	676.51	685.14	685.85	685.37	684.31E	683.72	682.64	682.12E	681.39	680.36	28
29	678.40G	.00	676.27	685.10	685.97	685.23	684.26E	683.64	682.57	682.11G	681.15	680.10	29
30	678.30G	.00	676.50	685.13	685.90	684.88	684.19E	683.46	682.62	682.09E	681.27	680.05	30
31	678.20G	.00	676.68	.00	685.72	.00	684.17E	683.32	.00	682.07G	.00	679.96	31
MAX	682.20	679.80	676.68	685.26	686.13	686.16	685.75	684.33	685.70	683.24	682.05	681.43	MAX
AVE	679.68	677.19	676.27	679.72	685.68	685.58	684.67	683.67	683.28	682.25	681.85	680.94	AVE
MIN	678.20	676.40	676.05	676.23	685.20	684.88	684.17	681.89	682.57	681.20	680.95	679.96	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

20 JAN 1972

1970 LAKE ATHABASCA AT FORT CHIPEWYAN 07MD001 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	679.80G	676.40G	675.39	675.94	683.18	683.95	684.63	684.33	683.87	682.22	681.42	681.09	1
2	679.60G	676.30G	675.43	675.79	682.86	684.01	684.38	684.48	684.92	682.42	681.46	681.08	2
3	679.40G	676.30G	675.42	675.86	682.80	684.22	684.23	684.51	684.37	682.79	681.47	681.07	3
4	679.20G	676.20G	675.24	676.18	683.13	683.90	684.23	684.59	683.61	682.66	681.38	680.93	4
5	678.97	676.20	675.31	676.12	683.15	683.40	683.98	684.72	682.98	681.98	681.65	680.89	5
6	678.92	676.25	675.56	676.24	683.38	684.01	684.09	684.48	682.90	681.92	681.36	680.97	6
7	678.95	676.04	675.84	676.24	682.81	684.68	684.05	684.77	682.13	682.20	681.15	680.79	7
8	678.95	676.11	675.84	676.57	682.15	684.53	683.60	684.22	682.04	682.27	681.03	680.77	8
9	678.91	675.95	675.85	676.77	682.55	684.29	684.40	683.29	682.85	681.99	681.05	680.72	9
10	678.52	676.01	675.82	676.88	682.74	684.20	684.75	682.81	683.21	682.04	680.92	680.81	10
11	678.07	676.15	675.71	677.00	683.03	684.13	684.73	683.25	683.33	682.25	681.06	680.83	11
12	678.00	676.10	675.66	677.07	683.49	683.83	684.21	684.16	682.97	682.19	681.10	680.81	12
13	677.90G	676.01	675.73	677.15	683.64	684.24	684.55	684.50	682.93	681.97	680.91	680.82	13
14	677.80G	675.78	675.69	677.49	683.75	684.33	684.62	684.32	682.64	681.92	680.91	680.77	14
15	677.70G	675.84	675.58	677.80	683.72	684.28	684.67	684.23	683.12	682.07	680.96	680.67	15
16	677.60G	675.59	675.55	678.09	683.90	684.17	683.89	683.83	683.16	681.39	681.10	680.50	16
17	677.50G	675.72	675.44	678.43	684.80	684.40	685.16	683.54	683.27	681.91	680.88	680.46	17
18	677.40G	675.73	675.49	678.91	682.93	683.99	685.05	683.66	683.24	682.63	680.98	680.39	18
19	677.30G	675.82	675.58	679.49	683.15	684.00	684.62	684.04	682.88	682.25	681.06	680.44	19
20	677.20G	675.84	675.48	679.99	683.23	684.17	684.62	683.83	682.86	682.32	681.17	680.43	20
21	677.10G	675.69	675.55	680.55	683.67	684.45	684.70	683.78	682.86	682.20	681.25	680.40G	21
22	677.00G	675.90	675.53	681.27	684.20	684.70	684.16	683.70	683.00	681.81	681.25	680.35G	22
23	676.90G	675.75	675.68	681.83	684.51	684.87	684.34	683.93	683.37	681.93	681.31	680.30G	23
24	676.80G	676.03	675.61	682.30	684.18	684.29	685.13	683.68	682.70	681.48	681.31	680.25G	24
25	676.70G	675.73	675.68	682.70	684.27	683.72	684.92	684.16	682.16	681.92	681.24	680.20G	25
26	676.70G	675.43	675.66	682.89	684.18	684.08	684.63	684.24	682.22	681.62	681.23	680.15G	26
27	676.60G	675.21	675.85	683.07	683.92	684.45	684.58	683.67	682.22	681.27	681.08	680.10G	27
28	676.60G	675.27	675.82	683.52	683.98	685.32	684.67	683.82	682.37	681.55	681.06	680.05G	28
29	676.50G	.00	675.72	683.65	683.95	685.68	684.69	683.77	682.33	681.86	680.98	680.00G	29
30	676.50G	.00	675.65	683.69	683.80	684.76	684.45	683.49	681.83	681.82	681.06	679.95G	30
31	676.40G	.00	675.84	.00	683.98	.00	683.53	683.41	.00	681.47	.00	679.90G	31
MAX	679.80	676.40	675.85	683.69	684.80	685.68	685.16	684.77	684.92	682.79	681.65	681.09	MAX
AVE	677.79	675.91	675.62	678.98	683.52	684.30	684.46	683.97	682.94	682.01	681.16	680.54	AVE
MIN	676.40	675.21	675.24	675.79	682.15	683.40	683.53	682.81	681.83	681.27	680.88	679.90	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ATHABASCA AT FORT CHIPEWYAN - STATION NO. 07MD001

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	676.99	684.58	684.13	685.00	686.74	685.70	683.45	682.63	---	1
2	---	---	---	677.14	684.48A	684.22	685.16	686.63	686.41	683.50	682.45	---	2
3	---	---	---	676.82	684.03A	684.34	685.38	686.50	685.49	683.47	682.38	---	3
4	679.67A	---	---	676.92	683.93A	684.19	685.23	686.47	684.92	683.39	682.52	---	4
5	679.67	---	---	676.79	683.88A	684.76	685.48	686.80	685.12	683.41	682.39	---	5
6	679.63	---	---	677.00	683.92A	684.42	685.56	686.39	684.64	683.36	682.39	---	6
7	679.44	---	---	676.87	683.96A	684.20	685.58	686.56	684.49	682.61	682.49	682.11A	7
8	679.30	---	---	676.61	681.16A	684.47	685.39	686.15	684.42	683.33	682.40	---	8
9	679.10	---	---	676.92	684.23A	684.33	685.48	686.23	684.54	682.87	682.50	---	9
10	678.82	---	---	676.83	684.25A	684.11	685.68	686.28	684.72	683.13	682.57	---	10
11	678.61	---	---	676.75	684.17A	684.16	685.55	686.21	684.49A	683.47	682.40	---	11
12	678.64	---	---	676.73	684.66A	684.85	685.35	686.24	683.80A	682.63	682.51	---	12
13	678.56	---	---	676.72	685.05A	684.08	685.40	685.52	683.44A	683.73	682.50	682.10A	13
14	---	---	---	676.72	684.89A	684.64	685.58	686.25	684.07	683.55	682.48	---	14
15	---	675.41A	---	676.66	684.73A	684.94	686.23	686.61	684.76	683.29	682.35	681.80A	15
16	---	675.27A	676.39A	676.64	684.02A	684.74	686.10	686.24	684.46	682.89	682.55	681.94	16
17	---	---	676.31	676.77	683.49A	684.42	686.02	685.99	684.53	682.88	682.46	681.79	17
18	---	675.61A	676.22	677.08	684.43A	684.64	686.20	685.98	684.07	682.78	682.57	681.77	18
19	---	675.63A	676.31	677.26	684.41	684.54	686.25	686.07	684.11	682.87	682.58	681.76	19
20	---	---	676.29	677.58	684.45	684.39	686.48	686.17	684.34	682.78	682.54	681.63	20
21	---	---	676.34	678.15	684.58	684.53	686.67	686.02	683.96	682.65	682.59	681.61	21
22	---	---	676.35	678.72	684.42	684.85	686.86	685.63	684.31	682.70	682.59	681.58	22
23	---	---	676.50	679.34	684.30	685.32	687.23	685.35	684.58	682.67	682.59	681.58	23
24	---	---	676.51	680.23	684.67	685.30	686.70	685.39	685.15	682.69	682.60	681.55	24
25	---	---	676.50	680.83	684.37	685.42	686.64	685.41	685.45	681.55	682.56	681.42	25
26	---	---	676.68	681.50	684.33	687.14	686.92	685.24	684.30	682.45	682.57	681.37	26
27	---	---	676.80	682.63	684.40	685.48	686.81	685.47	683.73	682.70	682.59	681.42	27
28	---	---	676.64	684.04	684.28	684.74	686.81	685.47	682.98	682.52	682.60	681.38	28
29	---		676.85	684.82	684.61	685.02	686.55	685.32	683.36	682.01	682.60A	681.46	29
30	---		676.88	684.82	684.57	684.99	686.57	685.29	683.39	682.42	---	681.39	30
31	---		676.80		684.20		686.70	685.39		682.48		681.34	31

SUMMARY FOR THE YEAR 1971
MAXIMUM DAILY WATER LEVEL, 687.23 FT ON JUL 23

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 42 40 N
LONG 111 08 50 W

A-MANUAL GAUGE

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

REVISED DATA TO 1970
AVAILABLE FROM DISTRICT

Lake Athabasca at Fort Chipewyan Station No. 07MD001

Daily Elevations in Feet for the Year 1972

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	681.35	678.94	676.80	676.77	682.69	685.57	688.38	688.38	686.92			
2	681.34	678.65	676.59	676.39	682.98	686.30	688.28	688.50	.69			
3	681.33	678.38	676.58	676.56	684.04	686.49	688.34	688.18	685.89			
4	681.37	678.20	676.59	676.87	684.78	686.07	688.43	688.41	686.71			
5	681.34	678.06	676.47	677.17	684.58	686.57	688.52	688.35	.77			
6	681.24	677.94	676.69	677.06	684.91	686.36	688.58	688.24	.57			
7	681.17	677.95	676.56	677.22	684.85	686.63	688.54	688.25	.64			
8	681.25	677.80	677.36	677.34	684.78	687.13	688.53	688.26	.57			
9	681.16	677.34	676.23	677.24	684.76	686.96	688.87	688.09	.50			
10	680.87	677.15	676.38	677.40		686.80	689.60	687.97	.45			
11	680.92	677.40	676.63	677.53		686.82	688.65	688.18	.45			
12	680.89	677.48	676.61	677.40		686.69	688.54	688.27	.34			
13	680.89	677.75	676.78	677.18		687.03	688.60	687.98	.22			
14		677.70	676.72	677.11		687.07	688.44	687.88	.69			
15		678.17	676.68	677.05		686.84	688.41	687.79	.17			
16		678.04	676.61	676.75		686.82	688.60	687.68	.49			
17		677.41	676.62	676.94		687.71	688.75	687.93	.08			
18		677.27	676.84	677.17		687.41	688.65	687.90	.19			
19		677.22	676.69	677.55		687.14	688.67	.68	.81			
20		677.23	676.59	677.43		687.33	688.65	.64	.59			
21		677.02	676.74	677.77		687.48	688.90	.54	.23			
22		677.09	676.55	678.24		687.74	688.89	.58	.64			
23		677.14	676.29	678.31		687.93	688.70	.53	685.45			
24		677.05	676.41	678.95		687.97	689.01	.48	684.75			
25		677.07	676.40	679.21		688.06	688.95	.13	685.14			
26		677.02	676.16	679.48	686.39	687.95	688.53	686.89				
27	679.54	676.84	676.15	680.53	686.20	687.89	688.44	.88				
28	679.59	676.77	676.15	681.58	686.56	687.90	688.19	687.28				
29	679.44	676.80	676.16	682.19	686.63	687.79	687.88	686.42				
30	679.16		676.28	682.49	686.52	687.85	688.47	687.17				
31	679.06		676.28		687.01		688.23	686.93				
	680.66	677.54	676.53	678.02	685.17	687.14	688.58	687.75	686.31			

1936 LAKE ATHABASCA AT GOLDFIELDS 07MC002 1936

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.46	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.46	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.26	.00	15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.16	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.86	.00	.00	22
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.59	.00	.00	31
MAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.86	688.46	688.46	MAX
AVE	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.72	688.36	688.31	AVE
MIN	.00	.00	.00	.00	.00	.00	.00	.00	.00	688.59	688.26	688.16	MIN
NO.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	2.	2.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.24	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	686.52	.00	684.80	.00	.00	.00	.00	.00	.00	.00	.00	3
4	687.76	.00	.00	.00	.00	.00	.00	687.85	.00	685.26	.00	.00	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	685.40	.00	685.98	.00	688.66	.00	686.44	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	683.76	.00	8
9	687.56	.00	.00	.00	.00	.00	.00	687.55	.00	.00	.00	.00	9
10	.00	686.26	.00	.00	.00	687.58	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	686.28	.00	.00	.00	.00	685.06	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	686.49	.00	.00	.00	686.36	.00	.00	.00	13
14	687.36	.00	.00	.00	.00	.00	688.58	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15
16	.00	686.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	.00	.00	687.09	.00	.00	.00	.00	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.58	.00	.00	18
19	.00	.00	.00	.00	686.63	.00	688.21	.00	.00	.00	.00	.00	19
20	687.06	.00	685.17	.00	.00	.00	.00	.00	686.05	.00	.00	.00	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	681.94	22
23	.00	.00	.00	.00	686.77	.00	.00	.00	.00	.00	.00	.00	23
24	.00	685.78	.00	.00	.00	.00	.00	686.85	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	688.41	.00	.00	.00	684.36	.00	.00	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	26
27	686.86	.00	.00	.00	686.93	.00	688.17	.00	685.60	.00	.00	681.91	27
28	.00	.00	.00	.00	.00	688.56	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	.00	686.92	.00	.00	.00	.00	31
MAX	687.76	686.52	685.40	684.80	686.93	688.56	688.66	687.85	686.44	685.26	684.24	681.94	MAX
AVE	687.52	686.14	685.28	684.80	686.51	688.18	688.40	687.25	686.11	684.81	684.00	681.92	AVE
MIN	686.86	685.78	685.17	684.80	685.98	687.58	688.17	686.85	685.60	684.36	683.76	681.91	MIN
NO.	5.	4.	2.	1.	6.	3.	4.	5.	4.	4.	2.	2.	DAY

1938	LAKE ATHABASCA AT GOLDFIELDS	07MC002	1938

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	681.92G	681.99G	682.14G	682.26	682.77	683.67	685.07	685.05	684.08	683.07	681.88	681.40	1
2	681.92G	681.99	682.15	682.36	682.82	683.82	685.07	685.15	683.92	682.73	681.89	681.42	2
3	681.92G	681.99G	682.15G	682.33	682.89	683.92	685.11	685.00	683.90G	683.12	681.74	681.40	3
4	681.92G	681.99G	682.16G	682.30	682.96	683.95	685.16	684.95	683.90G	683.24	681.80	681.50	4
5	681.93	681.99G	682.17G	682.33	683.08	684.12	685.11	684.59E	683.87	683.12	681.74	681.40G	5
6	681.93G	681.99G	682.13G	682.32	683.16	684.16	685.29E	684.90	683.30	682.71	681.74	681.30	6
7	681.94G	681.99G	682.19G	682.34	683.17	684.24	685.20G	684.85	683.50G	682.71	681.50	681.38	7
8	681.95G	681.99G	682.20G	682.34	683.25	684.28	685.16	684.85	683.62	682.63	681.76	681.35	8
9	681.96G	681.99	682.20	682.24	683.28	684.40	685.37	684.80	683.69E	682.63	681.80	681.36	9
10	681.97G	682.00G	682.20G	682.39	683.33	684.39	685.30G	684.72	683.62	682.60	681.80	681.39	10
11	681.98G	682.00G	682.21G	682.37	683.35	684.41	685.30G	684.70	683.59E	682.52	681.75G	681.40G	11
12	681.99	682.00G	682.22G	682.40	683.45	684.32	685.33	684.70	683.65	682.72	681.74	681.40	12
13	681.99G	682.00G	682.23G	682.50	683.53	684.35	685.52	684.62	683.55	682.71	681.70	681.48	13
14	681.99G	682.00G	682.24G	682.42	683.50	684.45	685.45	684.50G	683.60G	682.70G	681.70	681.50	14
15	681.98G	682.00G	682.24G	682.42	683.53	684.45	685.44G	684.45	683.70G	682.70	681.60	681.40	15
16	681.98G	682.02	682.25G	682.46	683.52	684.48	685.43	684.45G	683.89E	682.70	681.80	681.40	16
17	681.98G	682.02G	682.25	682.51	683.52	684.50G	685.44	684.45	683.60G	682.48	681.60	681.50	17
18	681.97G	682.02G	682.10	682.52	683.51	684.51	685.28	684.69E	683.49E	682.42	681.60	681.40	18
19	681.97	682.02G	682.17	682.46	683.51	684.65	685.36	684.40	683.19E	682.40G	681.60	681.50	19
20	681.97G	682.02G	682.21	682.52	683.46	684.67	685.40	684.40E	683.20G	682.35	681.54	681.45	20
21	681.98G	682.02G	682.22	682.40	683.44	684.77	685.39	684.35E	683.30G	682.29	681.53	681.52	21
22	681.98G	682.02G	682.25	682.54	683.53	684.73	685.40	684.30	683.31	682.28	681.55	681.50	22
23	681.98G	682.02	682.23	682.54	683.54	684.81	685.30	684.35	683.26	682.12	681.52	681.51	23
24	681.99G	682.03G	682.26	682.51	683.53	684.75	685.30G	684.30G	683.25	682.00	681.50	681.50	24
25	681.99G	682.04G	682.27	682.55	683.51	684.70	685.30	684.20G	683.26	682.00G	681.50	681.50G	25
26	681.99	682.05G	682.26	683.09	683.51	684.80G	685.27	684.09E	683.24	682.04	681.60	681.50G	26
27	681.99G	682.06G	682.33	682.67	683.67	684.85	685.32	684.00	683.15	682.34	681.60G	681.50	27
28	681.99G	682.07G	682.26	682.65	683.60	684.93	685.11G	684.00G	683.21	682.17	681.50	681.51	28
29	681.99G	.00	682.35	682.72	683.55	684.95	685.35	684.19E	683.12	682.19	681.50	681.51	29
30	681.99G	.00	682.34	682.80	683.47	684.94	685.14	684.10G	683.14	682.04	681.40	681.50	30
31	681.99G	.00	682.29	.00	683.53	.00	685.15	684.10G	.00	681.92	.00	681.60	31
MAX	681.99	682.07	682.35	683.09	683.67	684.95	685.52	685.15	684.08	683.24	681.89	681.60	MAX
AVE	681.97	682.01	682.22	682.48	683.37	684.47	685.28	684.52	683.50	682.50	681.65	681.45	AVE
MIN	681.92	681.99	682.10	682.24	682.77	683.67	685.07	684.00	683.12	681.92	681.40	681.30	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

LAKE ATHABASCA AT GOLDFIELDS 07MC002

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	681.45	681.76	681.90	682.20	683.00	684.74	686.26	686.35E	685.50	684.25	683.50	683.36	1
2	681.40	681.76	681.90G	682.20	683.10	684.89	686.30	686.80	685.25	684.28	683.50	683.25	2
3	681.44	681.76	681.96	682.19	683.11	685.04	686.35	686.70	685.35	684.30	683.60	683.42	3
4	681.40	681.76	681.95	682.19	683.20	685.15	686.36	686.60	684.85	684.20G	683.60G	683.50	4
5	681.41	681.77	681.93	682.20	683.25	685.15	686.40	686.65	685.18	684.00	683.50	683.46	5
6	681.48	681.79	681.90	682.23	683.27	685.16	686.30	686.60	685.45	684.05	683.54	683.54	6
7	681.48	681.79	681.90	682.23	683.39	685.20	686.25	686.58	685.20	683.90	683.00	683.44	7
8	681.48	681.80	681.93	682.20	683.39	685.30	686.35	686.40	685.20G	683.90G	683.30	683.52	8
9	681.48	681.80	681.95	682.23	683.41	685.44	686.35G	686.40	685.18	683.88	683.40	683.54	9
10	681.48	681.79	681.95	682.23	683.41	685.48	686.35	686.40	685.28	683.88	683.45	683.47	10
11	681.48	681.78	681.93	682.23	683.50	685.80	686.35	686.25	685.15	683.90	683.08	683.58	11
12	681.48	681.79	681.97	682.23	683.49	685.70	687.00	686.30	685.00	683.92	683.00	683.47	12
13	681.47	681.79	681.99	682.23	683.49	685.80	686.25	686.40	685.00	683.90	682.90	683.55	13
14	681.47	681.80	681.98	682.33	683.49	685.79	686.45	686.35	685.05	683.80G	682.90G	683.51	14
15	681.47	681.79	681.97	682.24	683.49	685.83	686.45	686.40	684.80	683.70	683.00G	683.56	15
16	681.58	681.80	681.99	682.23	683.49	685.90	686.48	686.50G	684.95	683.75	683.00G	683.53	16
17	681.57	681.80	681.99	682.25	683.50	685.94	686.55	686.70	684.85	683.50	683.10G	683.50G	17
18	681.59	681.81	682.00	682.29	683.67	685.94	686.50	686.10	684.90G	683.60	683.20G	683.50G	18
19	681.59	681.86	682.04	682.31	683.69	685.94	686.05E	686.15	684.95	683.65	683.38	683.50G	19
20	681.64	681.88	682.05	682.37	683.49	686.15	686.48	686.10	684.95	683.60	683.48	683.50G	20
21	681.59	681.87	682.05	682.40	683.67	686.10	686.46	686.09	684.70	683.50	683.32	683.50G	21
22	681.59	681.87	682.08	682.33	683.70	685.90	686.47	685.99	684.68	683.65	683.28	683.50G	22
23	681.64	681.90	682.09	682.47	683.50	686.05	686.40	686.05	684.50	683.68	683.40	683.50G	23
24	681.60	681.90	682.10	682.40	683.49	686.00	686.49	685.95	684.40	683.63	683.37	683.57	24
25	681.67	681.90	682.13	682.43	683.87	686.00	686.48	685.84	684.40	683.54	683.40	683.58	25
26	681.66	681.90	682.13	682.48	683.94	686.00	686.65	685.70	684.45	683.65	683.39	683.57	26
27	681.65	681.88	682.12	682.59	683.94	686.05	686.60	685.70	684.35	683.50	683.38	683.52	27
28	681.68	681.90	682.13	682.59	684.26	686.27	686.60	685.60	684.40	683.90	683.50	683.54	28
29	681.68	.00	682.15	682.68	684.39	686.25	686.60G	685.10	684.48	683.80	683.25	683.52	29
30	681.70	.00	682.17	682.88	684.38	686.20	686.65	685.50	684.25	684.00	683.34	683.50	30
31	681.74	.00	682.19	.00	684.39	.00	686.70	685.65	.00	683.30	.00	683.53	31
MAX	681.74	681.90	682.19	682.88	684.39	686.27	687.00	686.80	685.50	684.30	683.60	683.58	MAX
AVE	681.55	681.82	682.02	682.34	683.59	685.71	686.45	686.19	684.89	683.81	683.30	683.50	AVE
MIN	681.40	681.76	681.90	682.19	683.00	684.74	686.05	685.10	684.25	683.30	682.90	683.25	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.10G	683.04	682.89	683.09	683.78	686.20	687.60G	687.25E	686.08	684.05	682.65	682.30G	1
2	683.47	683.03	682.90	683.08	683.91	686.38	687.65E	687.35E	685.90	684.20	682.50	682.30G	2
3	683.41	683.01	682.90	683.10	684.05	686.50	687.60	687.10G	685.80	684.15	682.50	682.30G	3
4	683.40	683.03G	682.92	683.09	684.20	686.52	687.68	686.85E	685.70	684.10	682.50G	682.30G	4
5	683.41	683.05	682.89	683.10	684.31	686.45	687.80	685.85E	685.80	684.10	682.50	682.30G	5
6	683.50	683.04	682.94	683.09	684.50	686.60G	687.70	686.55E	685.75	684.00	682.45	682.30G	6
7	683.48	683.06	682.94	683.12	684.70	686.70	687.60G	687.20	685.75	684.00	682.40G	682.30	7
8	683.45	682.98	682.96	683.17	684.86	686.71	687.60G	687.10	685.70	683.90	682.40G	682.30G	8
9	683.32	682.95	682.97	683.15	684.96	686.74	687.60G	687.00	685.50	683.90	682.40G	682.30	9
10	683.38	682.99	682.96	683.15G	684.96	686.75	687.50G	687.00	685.45	683.75	682.40G	682.30	10
11	683.35	682.98	682.97	683.15G	685.06	686.90	687.50G	687.00	685.40	683.70	682.40G	682.30	11
12	683.32	682.96	682.99	683.15G	685.30	686.88	687.50G	687.00	685.35	683.65	682.40G	682.30	12
13	683.42	682.92	682.92	683.15G	685.30	687.06	687.50G	687.00	685.30	683.50	682.40G	682.30	13
14	683.39	682.88	683.03	683.15G	685.32	687.10	687.50G	686.95	685.40	683.50	682.40G	682.30	14
15	683.34	682.95	682.92	683.16	685.30	687.12	687.40G	686.80	685.10	683.50	682.30	682.30	15
16	683.33	682.92	682.98	683.08	685.45	687.12	687.40G	686.75	685.15	683.50	682.30	682.30	16
17	683.30	682.90	683.00G	683.09	685.48	687.05E	687.40G	686.75	685.15	683.25	682.30	682.40	17
18	683.26	682.92	683.00	683.12	685.54	686.85E	687.40G	686.60	685.10	683.25	682.25	682.40	18
19	683.26	682.93	683.08	683.16	685.58	687.15E	687.35E	686.60	685.05	683.05	682.20G	682.40	19
20	683.23	682.94	683.07	683.16	685.72	687.00G	687.25E	686.60	685.00	683.20	682.20G	682.40	20
21	683.20G	682.95	683.10	683.16	685.50	686.95E	687.35E	686.45	684.85	683.25	682.20G	682.40	21
22	683.20G	682.93	683.12	683.20	685.70	687.25G	687.35E	686.40	684.80	683.25	682.20	682.40	22
23	683.20G	682.95	683.10	683.20	685.75	687.56	687.35E	686.35	684.70	683.00	682.30	682.40	23
24	683.20G	682.94	683.09	683.17	685.75	688.00	687.35E	686.30	684.70	683.00	682.30G	682.40	24
25	683.20G	682.95G	683.24	683.20	685.75	687.30	687.35E	686.25	684.70	683.30	682.30G	682.40	25
26	683.20G	682.95	683.05	683.26	685.85	687.20	687.45E	686.40	684.65	683.30	682.30G	682.40	26
27	683.20G	682.91	683.03	683.35	685.90	687.50	687.40G	686.15	684.50	682.90G	682.30G	682.40	27
28	683.14	682.93	683.05	683.41	685.95	687.60	687.35E	686.10	684.35	682.50	682.30G	682.40	28
29	683.12	682.88	683.06	683.50	686.04	687.50	687.25E	686.00	684.50	682.75	682.30G	682.40	29
30	683.12	.00	683.05	683.64	686.10	687.60	687.15E	685.95	684.30	682.80	682.30G	682.40	30
31	683.08	.00	683.05G	.00	686.15	687.60	686.35E	686.00	.00	682.75	.00	682.40	31
MAX	683.50	683.06	683.24	683.64	686.15	688.00	687.80	687.35	686.08	684.20	682.65	682.40	MAX
AVE	683.29	682.96	683.01	683.19	685.25	687.03	687.43	686.63	685.18	683.45	682.35	682.35	AVE
MIN	683.08	682.88	682.89	683.08	683.78	686.20	686.35	685.85	684.30	682.50	682.20	682.30	MIN
NO.	31.	29.	31.	30.	31.	31.	31.	31.	30.	31.	30.	31.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	682.40	682.50	682.80	683.10	684.20	685.08	686.30E	686.00	684.70G	684.15G	684.20	683.95	1
2	682.40	682.60	682.80	683.10	684.10	685.07	685.90E	685.80G	684.70G	684.15G	683.90	683.80	2
3	682.40	682.60	682.80	683.10	684.20	685.08	685.78	685.48	684.70G	684.15G	684.15	684.10	3
4	682.40	682.60	682.80	683.10	684.20	685.07	685.80	685.58	684.68	684.15G	684.02	683.40	4
5	682.40	682.60	682.80	683.10	684.20	685.07	685.82	685.60E	684.63	684.15G	684.10	683.10	5
6	682.40	682.60	682.80	683.10	684.20	685.06	685.90	685.78	684.58	684.15G	684.05	682.80	6
7	682.40	682.70	682.90	683.10	684.20	684.98	685.98	685.78	684.53	684.15G	683.95	683.20	7
8	682.40	682.70	682.90	683.10	684.20	684.98	686.04	685.78	684.48	684.15G	683.95	682.90	8
9	682.40	682.70	682.90	683.10	684.20	685.07	686.00	685.68	684.38	684.15G	683.95	682.88	9
10	682.40	682.70	682.90	683.10	684.30	685.23	686.08	685.25E	684.38	684.15G	684.05	682.85	10
11	682.40	682.70	682.90	683.10	684.30	685.12	686.13	685.63	684.28	684.15G	684.02	682.78	11
12	682.40	682.70	682.90	683.10	684.20	685.18	686.10	686.00E	684.23	684.15G	684.05	682.50	12
13	682.40	682.70	682.90	683.10	684.40	685.23	686.12	684.95E	684.18	684.15G	683.87	682.50	13
14	682.40	682.70	683.00	683.10	684.40	685.32	686.08	685.58	684.08	684.15G	683.95	682.55	14
15	682.40	682.80	683.00	683.10	684.40	685.32	686.20E	685.50G	684.03	684.15G	684.00	682.80	15
16	682.40	682.80	683.00	683.10	684.40	685.38	685.90E	685.50G	683.98	684.15G	684.05	683.40	16
17	682.40	682.80	683.00	683.10	684.40	685.38	686.05E	685.50G	683.98	684.15G	683.95	683.25	17
18	682.40	682.70	683.00	683.10	684.50	685.43	686.05	685.48	683.98	684.15G	683.92	683.20	18
19	682.40	682.70	683.00	683.10	684.60	685.43	686.48	685.48	684.00G	684.15G	683.95	683.25	19
20	682.40	682.80	683.00	683.20	684.70	685.43	686.30G	685.38	684.00G	684.15G	683.95	683.40	20
21	682.40	682.80	683.00	683.30	684.70	685.53	686.18	685.28	684.08	684.15G	683.90	683.72	21
22	682.40	682.80	683.00	683.30	684.80	685.50E	686.08	685.24	684.18	684.15G	684.00	683.75	22
23	682.40	682.80	683.00	683.40	684.90	685.38	686.08	685.08	684.18	684.15G	683.92	683.72	23
24	682.40	682.80	683.00	683.50	685.00	685.58	686.08	685.08	684.18	684.15G	684.20	683.80	24
25	682.40	682.80	683.00	683.60	685.00	685.58	686.08	685.08	684.13	684.15G	684.25	683.80	25
26	682.40	682.80	683.00	683.70	685.10	685.53	686.08	685.05G	684.15G	684.15G	684.32	683.82	26
27	682.50	682.80	683.00	683.80	685.10	685.63	685.96	685.05G	684.15G	684.15	684.25	683.65	27
28	682.50	682.80	683.00	684.00	684.99	685.60G	685.98	685.03	684.15G	684.12	684.15	683.70	28
29	682.50	.00	683.00	684.10	685.08	685.58	686.00	684.98	684.15G	684.15	684.30	683.70	29
30	682.50	.00	683.00	684.10	685.03	685.73	686.00G	684.88	684.15G	684.20	684.00	683.75	30
31	682.50	.00	683.10	.00	685.02	.00	686.00G	684.78	684.15G	684.25	.00	683.75	31
MAX	682.50	682.80	683.10	684.10	685.10	685.73	686.48	686.00	684.70	684.25	684.32	684.10	MAX
AVE	682.42	682.72	682.94	683.30	684.55	685.32	686.05	685.40	684.26	684.15	684.04	683.35	AVE
MIN	682.40	682.50	682.80	683.10	684.10	684.98	685.78	684.78	683.98	684.12	683.87	682.50	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	31.	31.	30.	31.	DAY

12 AUG 1970

1942 LAKE ATHABASCA AT GOLDFIELDS 07MC002 1942

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.60	683.38	683.15	683.35	683.80	685.57	.00	.00	.00	.00	.00	.00	1
2	683.70	683.42	683.10	683.32	683.98	685.68	.00	.00	.00	.00	.00	.00	2
3	683.65	683.35	683.12	683.35	684.00	685.75E	.00	.00	.00	.00	.00	.00	3
4	683.60	683.40	683.15	683.38	684.10	685.90	.00	.00	.00	.00	.00	.00	4
5	683.75	683.38	683.15	683.35	684.25	685.78	.00	.00	.00	.00	.00	.00	5
6	683.75	683.42	683.15	683.38	684.40	686.08	.00	.00	.00	.00	.00	.00	6
7	683.70	683.42	683.20	683.38	684.45	686.18	.00	.00	.00	.00	.00	.00	7
8	683.50	683.40G	683.20	683.38	684.50	686.23	.00	.00	.00	.00	.00	.00	8
9	683.60	683.40G	683.25	683.38	684.50	686.20	.00	.00	.00	.00	.00	.00	9
10	683.50	683.40G	683.10	683.32	684.52	686.23	.00	.00	.00	.00	.00	.00	10
11	683.40	683.40G	683.08	683.35	684.55	686.48	.00	.00	.00	.00	.00	.00	11
12	683.40	683.35	683.15	683.30	684.55	686.53	.00	.00	.00	.00	.00	.00	12
13	683.42	683.35	683.15	683.35	684.60	686.68	.00	.00	.00	.00	.00	.00	13
14	683.42	683.15	683.20	683.42	684.60	686.87	.00	.00	.00	.00	.00	.00	14
15	683.40	683.22	683.15	683.40	684.65	686.78	.00	.00	.00	.00	.00	.00	15
16	683.40	683.30	683.20	683.38	684.65	686.83	.00	.00	.00	.00	.00	.00	16
17	683.50	683.25	683.20	683.35	684.70	686.73	.00	.00	.00	.00	.00	.00	17
18	683.55	683.25	683.20	683.45	684.70	686.72	.00	.00	.00	.00	.00	.00	18
19	683.50	683.30	683.25	683.45	684.75	687.13	.00	.00	.00	.00	.00	.00	19
20	683.50	683.28	683.25	683.42	684.82	687.18	.00	.00	.00	.00	.00	.00	20
21	683.45	683.30	683.30	683.42	684.95	687.23	.00	.00	.00	.00	.00	.00	21
22	683.45	683.18	683.30	683.52	684.98	687.28	.00	.00	.00	.00	.00	.00	22
23	683.40	683.10	683.32	683.52	685.05	687.33	.00	.00	.00	.00	.00	.00	23
24	683.40	683.08	683.35	683.45	684.90	687.43	.00	.00	.00	.00	.00	.00	24
25	683.45	683.05	683.30	683.50	684.90	687.58	.00	.00	.00	.00	.00	.00	25
26	683.60	683.10	683.32	683.52	685.00	687.68	.00	.00	.00	.00	.00	.00	26
27	683.60	683.08	683.30	683.60	684.90	687.83	.00	.00	.00	.00	.00	.00	27
28	683.60	683.08	683.28	683.62	685.00	688.35E	.00	.00	.00	.00	.00	.00	28
29	683.55	.00	683.25	683.70	685.10	688.25E	.00	.00	.00	.00	.00	.00	29
30	683.60	.00	683.32	683.75	685.10	688.40E	.00	.00	.00	.00	.00	.00	30
31	683.65	.00	683.30	.00	685.10	.00	.00	.00	.00	.00	.00	.00	31
MAX	683.75	683.42	683.35	683.75	685.10	688.40	.00	.00	.00	.00	.00	.00	MAX
AVG	683.54	683.28	683.22	683.44	684.65	686.83	.00	.00	.00	.00	.00	.00	AVF
MIN	683.40	683.05	683.08	683.30	683.80	685.57	.00	.00	.00	.00	.00	.00	MIN
NO.	31.	28.	31.	30.	31.	30.	0.	0.	0.	0.	0.	0.	DAY

12 AUG 1970

1952 LAKE ATHABASCA AT GOLDFIELDS 07MC002 1952

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.37	.00	.00	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	22
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31
MAX	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.37	.00	.00	MAX
AVE	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.37	.00	.00	AVE
MIN	.00	.00	.00	.00	.00	.00	.00	.00	.00	684.37	.00	.00	MIN
NO.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9
10	.00	681.54	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	22
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	.00	.00	.00	684.08	.00	.00	.00	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31
MAX	.00	681.54	.00	.00	.00	.00	.00	.00	684.08	.00	.00	.00	MAX
AVE	.00	681.54	.00	.00	.00	.00	.00	.00	684.08	.00	.00	.00	AVE
MIN	.00	681.54	.00	.00	.00	.00	.00	.00	684.08	.00	.00	.00	MIN
NO.	0.	1.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	DAY

12 AUG 1970

1954 LAKE ATHABASCA AT GOLDFIELDS 07MC002 1954

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6
7	.00	.00	.00	.00	.00	.00	.00	.00	689.05	.00	.00	.00	7
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8
9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9
10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14
15	682.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	16
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	17
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	18
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	20
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	21
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	22
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	23
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	24
25	.00	.00	.00	.00	.00	.00	690.75	.00	.00	.00	.00	.00	25
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	26
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	27
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	28
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29
30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30
31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31
MAX	682.25	.00	.00	.00	.00	.00	690.75	.00	689.05	.00	.00	.00	MAX
AVE	682.25	.00	.00	.00	.00	.00	690.75	.00	689.05	.00	.00	.00	AVE
MIN	682.25	.00	.00	.00	.00	.00	690.75	.00	689.05	.00	.00	.00	MIN
NO.	1.	0.	0.	0.	0.	0.	1.	0.	1.	0.	0.	0.	DAY

1956 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1956

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.34	682.53G	682.96	684.63E	687.10E	686.63	685.13	684.20G	683.16	682.82	1
2	.00	.00	682.28	682.55	683.06	685.35E	687.03E	686.63	685.10G	684.20G	683.19	682.80G	2
3	.00	.00	682.22	682.49	683.14	684.81E	686.69	686.58	685.10G	684.20G	683.29	682.80G	3
4	.00	.00	682.16	682.50G	683.33E	684.69E	686.71E	686.43	685.13	684.10G	683.20G	682.80G	4
5	.00	.00	682.20G	682.51	683.63E	684.96E	686.65E	686.13E	685.13	684.10G	683.17	682.77	5
6	.00	.00	682.20G	682.55	684.23E	684.63E	686.83	686.48	685.03	684.10G	683.09	682.70G	6
7	.00	.00	682.31	682.49	684.19E	684.27E	686.93	686.48	685.03	684.00G	683.05	682.71	7
8	.00	.00	682.32	682.50	683.64	684.10E	686.80E	686.47E	684.98	684.00G	682.99	682.72	8
9	.00	.00	682.31	682.52	683.71	684.85E	686.98	686.38	684.95G	684.00G	683.04	682.70G	9
10	.00	.00	682.33	682.52	683.68	685.00E	686.98	686.33	684.93	683.90G	682.99	682.60G	10
11	.00	.00	682.33	682.53	683.76	685.19E	686.93	686.28	684.83	683.90G	682.90G	682.62	11
12	.00	.00	682.33	682.59	683.70G	684.99E	686.93	686.35E	684.83	683.90G	682.87	682.56	12
13	.00	.00	682.33	682.59	683.70G	685.35E	686.93	686.23	684.78	683.80G	682.88	682.60G	13
14	.00	.00	682.33	682.60G	683.77	685.50E	686.83	686.33	684.78	683.80G	682.95	682.60	14
15	.00	.00	682.33	682.60G	683.80G	685.77E	686.80E	686.13	684.73	683.80G	682.88	682.60	15
16	.00	.00	682.45	682.60G	683.80G	685.85E	686.98	686.18	684.65G	683.72	682.93	.00	16
17	.00	.00	682.40	682.59	683.81	685.97E	686.98	686.03	684.58	683.74	682.93	.00	17
18	.00	.00	682.40G	682.59	683.50E	685.80E	687.03	686.03	684.58	683.81	682.94G	.00	18
19	.00	.00	682.44	682.61	683.90	686.07E	687.03	685.90E	684.48	683.71	682.94	.00	19
20	.00	.00	682.46	682.65	683.78	686.33E	687.03	685.73	684.48	683.53	682.85	.00	20
21	.00	.00	682.45	682.65	684.67E	686.00E	687.03	685.83	684.43	683.50G	682.85	.00	21
22	.00	.00	682.40	682.65G	683.77	686.41E	686.51E	685.83	684.47	683.45	682.83	.00	22
23	.00	.00	682.42	682.65	684.03E	686.57E	687.03	685.83	684.50G	683.18	682.85	.00	23
24	.00	.00	682.46	682.69	683.89	686.33E	686.93	685.73	684.40G	683.45	682.87	.00	24
25	.00	682.29	682.45	682.70	683.99E	686.65E	686.83	685.63	684.40G	683.43	682.86G	.00	25
26	.00	682.26	682.49	682.73	684.81E	686.43E	686.78	685.43E	684.40G	683.40	682.86	.00	26
27	.00	682.30	682.47	682.84	683.85E	686.40E	686.78	685.38	684.30G	683.40	682.80G	.00	27
28	.00	682.35	682.46	682.90G	684.07E	686.50E	686.68	685.43	684.30G	683.40G	682.72	.00	28
29	.00	682.23	682.50G	682.90G	684.53E	686.90E	687.05E	685.58	684.30G	683.35	682.77G	.00	29
30	.00	.00	682.50G	682.92	684.47E	687.10E	686.68	685.53	684.30G	683.28	682.83	.00	30
31	.00	.00	682.50G	.00	684.40E	.00	686.63	685.45	.00	683.17	.00	.00	31
MAX	.00	682.35	682.50	682.92	684.81	687.10	687.10	686.63	685.13	684.20	683.29	682.82	MAX
AVE	.00	682.29	682.37	682.62	683.86	685.65	686.87	686.04	684.70	683.73	682.95	682.69	AVF
MIN	.00	682.23	682.16	682.49	682.96	684.10	686.51	685.38	684.30	683.17	682.72	682.56	MIN
NO.	0.	5.	31.	30.	31.	30.	31.	31.	30.	31.	30.	15.	DAY

LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	681.94	.00	682.80G	685.63	686.70G	686.70	686.80G	685.64	684.26	.00	1
2	.00	.00	.00	.00	682.90G	685.70G	686.70	686.69	686.80G	685.49	684.20G	.00	2
3	.00	.00	.00	.00	683.00G	685.82	686.69	686.72	686.84	685.48	684.20G	.00	3
4	.00	.00	.00	.00	683.10G	685.94	686.75	686.70G	686.80	685.16	684.17	.00	4
5	.00	.00	.00	.00	683.20G	685.97	686.73	686.74	686.71	684.72	684.10G	.00	5
6	.00	.00	.00	.00	683.30G	686.07	686.73	686.79	686.78	685.00G	684.00	.00	6
7	.00	.00	.00	.00	683.41	686.12	686.70G	686.69	686.88	685.33	683.99	.00	7
8	.00	.00	.00	.00	683.52	686.22	686.76	686.68	686.80G	685.30	683.95	.00	8
9	.00	.00	.00	.00	683.65	686.30G	686.70	686.68	686.84	685.24	683.93	.00	9
10	.00	.00	.00	.00	683.74	686.33	686.79	686.59	686.72	685.21	683.90G	.00	10
11	.00	.00	.00	.00	683.85	686.37	686.78	686.50G	686.64	685.18	683.90G	.00	11
12	.00	.00	.00	.00	684.00G	686.33	686.73	686.53	686.63	685.06	683.89	.00	12
13	.00	.00	.00	.00	684.02	686.38	686.72	686.51	686.64	684.80G	683.88	.00	13
14	.00	.00	.00	.00	684.14	686.43	686.70G	686.44	686.42	684.51	683.87	.00	14
15	.00	.00	.00	.00	684.25	686.53	686.66	686.48	686.40G	684.48	683.85	.00	15
16	.00	.00	.00	.00	684.29	686.60G	686.76	686.44	686.42	684.50G	683.82	.00	16
17	.00	.00	.00	.00	684.29	686.67	686.60	686.44	686.42	684.50G	683.80G	.00	17
18	.00	.00	.00	.00	684.38	686.61	686.64	686.50G	686.44	684.50G	683.80G	.00	18
19	.00	.00	.00	.00	684.40G	686.72	686.62	686.54	686.22	684.50G	683.82	.00	19
20	.00	.00	.00	.00	684.47	686.74	686.64	686.65	686.22	684.40G	683.82	.00	20
21	.00	.00	.00	.00	684.55	686.74	686.70G	686.79	686.20	684.40G	683.79	.00	21
22	.00	.00	.00	.00	684.61	686.69	686.69	686.81	686.10G	684.40G	683.76	.00	22
23	.00	.00	.00	.00	684.68	686.70G	686.57	686.88	686.09	684.40G	683.74	.00	23
24	.00	.00	.00	.00	684.72	686.80	686.84	686.52	686.09	684.30G	683.70G	.00	24
25	.00	.00	.00	.00	684.81	686.88	686.79	686.70G	685.70	684.30G	683.59	.00	25
26	.00	.00	.00	.00	685.00G	686.78	686.69	686.84	685.84	684.30G	683.73	.00	26
27	.00	.00	.00	.00	685.01	686.81	686.59	686.91	685.84	684.30G	683.72	.00	27
28	.00	.00	.00	.00	685.05	686.76	686.70G	686.89	685.86	684.32	683.70G	.00	28
29	.00	.00	.00	.00	685.15	686.74	686.79	686.89	685.80G	684.44	683.70G	.00	29
30	.00	.00	.00	.00	685.39	686.70G	686.73	686.81	685.73	684.29	683.60G	.00	30
31	.00	.00	.00	.00	685.59	.00	686.69	686.81	.00	684.28	683.60G	.00	31
MAX	.00	.00	681.94	.00	685.59	686.88	686.84	686.91	686.88	685.64	684.26	.00	MAX
AVE	.00	.00	681.94	.00	684.17	686.44	686.71	686.67	686.39	684.73	683.86	.00	AVE
MIN	.00	.00	681.94	.00	682.80	685.63	686.57	686.44	685.70	684.28	683.59	.00	MIN
NO.	0.	0.	1.	0.	31.	30.	31.	31.	30.	31.	31.	0.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.50G	682.42G	684.80	687.30G	688.40G	687.50G	685.90G	684.45	683.40G	682.70G	1
2	.00	.00	682.50G	682.42	685.08	687.49	688.39	687.40G	685.81	684.35	683.30G	682.70G	2
3	.00	.00	682.50G	682.43G	685.15	687.55	688.38	687.30G	685.70G	684.31	683.31	682.67	3
4	.00	.00	682.50G	682.44G	685.20G	687.77	688.32	687.25	685.67	684.27	683.30G	.00	4
5	.00	.00	682.50G	682.46G	685.20G	687.86	688.32	687.23	685.65G	684.30G	683.28	.00	5
6	.00	.00	682.50G	682.48G	685.30G	688.00G	688.30G	687.28	685.63	684.20G	683.21	.00	6
7	.00	.00	682.50G	682.50G	685.37	688.15	688.30G	687.25	685.60G	684.20	683.20G	.00	7
8	.00	.00	682.50G	682.52G	685.42	688.20G	688.32	687.25	685.51	684.19	683.10G	.00	8
9	.00	.00	682.50G	682.53	685.46	688.25	688.34	687.22	685.50G	684.10G	683.10G	.00	9
10	.00	.00	682.50G	682.54G	685.55	688.39	688.34	687.10G	685.50G	684.07	683.09	.00	10
11	.00	.00	682.49	682.55G	685.60G	688.46	688.33	687.05	685.47	684.00G	683.00G	.00	11
12	.00	.00	682.49G	682.56G	685.61	688.50G	688.28	687.04	685.33	684.00G	683.00G	.00	12
13	.00	.00	682.49G	682.57G	685.79	688.57	688.30G	686.85	685.30G	684.00G	682.91	.00	13
14	.00	.00	682.49G	682.58G	685.86	688.60	688.32	686.80G	685.20G	683.98	682.91	.00	14
15	.00	.00	682.49G	682.60G	685.95	688.60G	688.30	686.82	685.16	683.96	683.90G	.00	15
16	.00	.00	682.49G	682.63	686.04	688.72	688.24	686.78	685.10G	683.90G	682.90G	.00	16
17	.00	.00	682.49G	682.70G	686.20	688.70G	688.28	686.70G	685.00G	683.86	682.90G	.00	17
18	.00	.00	682.49G	682.80G	686.20G	688.75	688.20G	686.60G	685.00G	683.84G	682.90	.00	18
19	.00	.00	682.48	682.90G	686.30G	688.77	688.12	686.53	684.92	683.82G	682.89	.00	19
20	.00	.00	682.48G	683.00G	686.31	688.80	688.10G	686.51	684.91	683.81	682.85	.00	20
21	.00	682.59	682.48G	683.10G	686.42	688.80G	688.03	686.30	684.90G	683.81	682.85G	.00	21
22	.00	682.60G	682.47G	683.20G	686.51	688.70G	688.00G	686.40	684.81	683.71	682.85G	.00	22
23	.00	682.60G	682.47G	683.21	686.55	688.70	688.04	686.40G	684.80	683.70G	682.85G	.00	23
24	.00	682.60G	682.46G	683.35	686.59	688.75	687.94	686.30G	684.72	683.65G	682.85G	.00	24
25	.00	682.60G	682.46G	683.50G	686.60G	688.71	687.84	686.30G	684.70G	683.61	682.85G	.00	25
26	.00	682.60G	682.45	683.70G	686.74	688.67	687.81	686.23	684.70G	683.60G	682.85	.00	26
27	.00	682.60G	682.45G	683.90G	686.81	688.60G	687.80G	686.20G	684.66	683.60	682.80G	.00	27
28	.00	682.60G	682.44E	684.15	686.82	688.59	687.74	686.12	684.60G	683.48	682.80G	.00	28
29	.00	.00	682.44G	684.37	686.98	688.60G	687.64	686.10G	684.52	683.46	682.80G	.00	29
30	.00	.00	682.33G	684.62	687.02	688.50G	687.62	686.03	684.50G	683.40G	682.80G	.00	30
31	.00	.00	682.43G	.00	687.15	.00	687.58	686.00G	.00	683.40G	.00	.00	31
MAX	.00	682.60	682.50	684.62	687.15	688.80	688.40	687.50	685.90	684.45	683.90	682.70	MAX
AVE	.00	682.60	682.48	682.96	686.02	688.40	688.13	686.74	685.16	683.90	683.02	682.69	AVE
MIN	.00	682.59	682.33	682.42	684.80	687.30	687.58	686.00	684.50	683.40	682.80	682.67	MIN
NO.	0.	8.	31.	30.	31.	30.	31.	31.	30.	31.	30.	3.	DAY

12 AUG 1970

1959 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1959

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	.00	.00	682.10G	682.30G	682.80G	684.30G	686.92	687.37	686.00G	685.31	684.70G	684.10	1
2	.00	.00	682.10G	682.30G	682.80G	684.36	686.97	687.35G	685.90G	685.31	684.72	684.10G	2
3	.00	.00	682.10G	682.40G	682.80G	684.45	687.12	687.32	685.90G	685.31G	684.72	684.10G	3
4	.00	.00	682.15	682.40G	682.80G	684.47	687.18	687.30G	685.90G	685.32G	684.70G	684.10G	4
5	.00	.00	682.20G	682.40G	682.80G	684.56	687.20G	687.20G	685.80G	685.32	684.67	684.00G	5
6	.00	.00	682.20G	682.40	682.89	684.69	687.30G	687.17	685.80G	685.32	684.65G	684.00G	6
7	.00	.00	682.20G	682.40G	682.90G	681.80G	687.30G	687.12	685.80G	685.30G	684.62	684.00G	7
8	.00	.00	682.20G	682.40G	682.90G	684.82	687.40G	687.10G	685.81	685.22	684.60G	684.05	8
9	.00	.00	682.25	682.40G	683.00G	684.89	687.40G	687.10G	685.81	685.12	684.60G	684.05	9
10	.00	.00	682.20G	682.40G	683.10G	684.92	687.50G	687.07	685.81	685.12	684.60G	684.07	10
11	.00	.00	682.20G	682.40G	683.14	684.99	687.50G	686.97	685.76	685.10G	684.60G	684.09	11
12	.00	.00	682.20G	682.40G	683.20G	685.00G	687.50G	686.97	685.71	685.10G	684.50G	684.10G	12
13	.00	.00	682.20G	682.40G	683.20G	685.20G	687.52	686.92	685.60G	685.10G	684.50G	684.10G	13
14	.00	682.14	682.30G	682.41	683.30G	685.40G	687.60G	686.82	685.51	685.10G	684.50G	684.06	14
15	.00	682.10G	682.30G	682.40G	683.30G	685.69	687.72	686.82	685.61	685.00G	684.50G	684.09	15
16	.00	682.10G	682.30G	682.40G	683.40G	685.70G	687.72	686.70G	685.66	685.00G	684.40G	684.00G	16
17	.00	682.10G	682.30G	682.40G	683.40G	685.71	687.70G	686.60G	685.56	685.00G	684.40G	684.01	17
18	.00	682.10G	682.33	682.50G	683.50G	685.80G	687.69	686.50	685.51	685.00G	684.40G	683.99	18
19	.00	682.10G	682.30G	682.50G	683.50G	685.90	687.60G	686.50	685.50G	684.97	684.40G	683.90	19
20	.00	682.10G	682.30G	682.50G	683.60G	685.93	687.62	686.48	685.50G	684.92	684.30G	683.90G	20
21	.00	682.10G	682.30G	682.50G	683.60G	686.00G	687.60G	686.40G	685.50G	684.92	684.30G	683.93	21
22	.00	682.10G	682.30G	682.60G	683.70G	686.12	687.67	686.32	685.46	684.92	684.30G	683.90	22
23	.00	682.12	682.36	682.59	683.70G	686.25	687.67	686.30G	685.46	684.82	684.30G	683.90	23
24	.00	682.10G	682.30G	682.60G	683.80G	686.32	687.70G	686.26	685.41	684.80	684.20G	683.85	24
25	.00	682.10G	682.30G	682.60G	683.80G	686.37	687.70G	686.17	685.31	684.80G	684.20G	683.85G	25
26	.00	682.10G	682.30G	682.70G	683.90G	686.47	687.70G	686.07	685.30G	684.80G	684.20G	683.85G	26
27	.00	682.10G	682.30G	682.69	683.90G	686.50G	687.72	686.00G	685.40G	684.80G	684.20G	683.85G	27
28	.00	682.10G	682.30G	682.70G	684.00G	686.60G	687.62	685.82	685.36	684.80G	684.10G	683.84	28
29	.00	.00	682.30G	682.70G	684.00G	686.77	687.60G	685.94	685.36	684.70G	684.10G	683.75	29
30	.00	.00	682.30G	682.70G	684.10G	686.82	687.52	686.00G	685.31	684.70G	684.10G	683.82	30
31	.00	.00	682.33	.00	684.20G	.00	687.52	685.90G	.00	684.70G	.00	683.76	31
MAX	.00	682.14	682.36	682.70	684.20	686.82	687.72	687.37	686.00	685.32	684.72	684.10	MAX
AVE	.00	682.10	682.25	682.48	683.39	685.43	687.50	686.66	685.61	685.02	684.44	683.97	AVE
MIN	.00	682.10	682.10	682.30	682.80	681.80	686.92	685.82	685.30	684.70	684.10	683.75	MIN
NO.	0.	15.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1960 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1960

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.70G	683.04	682.95	683.00G	683.93G	685.51	689.34E	690.36E	689.16E	688.30G	687.10	686.55	1
2	683.70G	683.01	682.95G	683.00G	683.95	685.66	689.07E	690.18E	688.05E	688.30G	687.10G	686.55G	2
3	683.70G	683.03	682.95	683.00G	684.02	685.76	689.14E	690.04	688.51E	688.20G	687.10	686.55G	3
4	683.06	683.03	682.95	682.95	684.10	686.50E	689.25	690.05E	688.73E	688.21	687.00G	686.55G	4
5	683.04	683.01	682.95G	683.10	684.12	686.24E	689.23E	690.03E	689.63E	688.21	686.90G	686.57	5
6	683.46	683.00G	682.95G	683.08	684.20	686.33E	689.55	689.99E	688.74	688.01	686.90G	686.55	6
7	683.54	683.00G	682.95	683.10	684.30E	686.94E	689.60	689.77E	688.74	688.10G	686.80	686.50G	7
8	683.47	683.00G	682.90	683.10G	684.13E	685.93E	689.92	689.94	688.74	688.10G	686.80G	686.50G	8
9	683.45G	683.00G	682.90	683.10G	683.74E	686.49E	690.25	689.84	688.48E	688.20G	686.80G	686.40G	9
10	683.43G	683.00	682.95	683.10G	684.25	686.98E	689.71E	689.81	688.72E	688.30G	686.80G	686.40G	10
11	683.42	683.00	682.95	683.10	684.25	686.81E	690.20	689.84	688.34E	687.91	686.80G	686.30G	11
12	683.41	682.90	682.95G	683.10	684.27	686.64E	690.30	689.83E	688.74	687.81	686.80G	686.27	12
13	683.36	682.90	682.95G	683.15	684.25	686.75	690.29	689.66E	689.35E	687.81	686.80G	686.27G	13
14	683.35	683.00G	682.95	683.08	684.30	686.75	690.25	689.60E	688.64	687.81	686.80G	686.27	14
15	683.34	683.00G	682.97	683.10G	683.67E	687.27E	690.55E	689.59	687.86E	687.80G	686.80G	686.25G	15
16	683.34	683.00G	682.95	683.10G	684.31	686.90	690.31	689.54	688.38E	687.70G	686.70G	686.25G	16
17	683.30G	683.00G	683.00	683.20G	684.36	687.24E	690.39E	689.54	688.64	687.71	686.70G	686.25G	17
18	683.35	683.00G	683.05	683.20	683.97E	687.31E	690.41	689.49	688.33E	687.71	686.70G	686.20G	18
19	683.31	683.00G	683.00G	683.20G	684.36	687.31E	690.31	689.39	688.64	687.70G	686.70G	686.20G	19
20	683.26	683.00G	683.00G	683.25	684.41	687.68E	690.39	689.21E	688.82E	687.61	686.70G	686.20G	20
21	683.27	683.00G	682.95	683.30	685.39E	687.58E	690.39	689.11E	688.69	687.60G	686.70G	686.20G	21
22	683.20G	683.00	683.00	683.38	685.14E	687.50E	690.32	689.04	688.64	687.60G	686.70G	686.10G	22
23	683.22	683.00G	683.00G	683.40G	684.43E	687.57E	690.34	689.18	688.64	687.50G	686.70G	686.10G	23
24	683.20G	683.00	683.00	683.40G	684.63	687.59E	690.70E	688.85G	688.64	687.50	686.70G	686.10G	24
25	683.20G	683.00	683.05	683.38	684.71	687.79E	690.34	689.19	688.84E	687.40G	686.60G	686.10G	25
26	683.20G	682.95	683.00G	683.47	685.22E	687.95E	690.24	689.09	688.46E	687.30G	686.60G	686.10G	26
27	683.20G	682.95	683.00G	683.50	684.76	687.92	690.24	688.86E	688.49E	687.15	686.60G	686.02	27
28	683.14	682.90G	683.00G	683.53	684.91	689.22E	690.24	688.95E	688.19E	687.10	686.60G	686.00G	28
29	683.10G	682.90G	683.00G	683.68	685.20E	688.25	690.24	689.11E	688.35E	687.00G	686.60G	685.97	29
30	683.10G	.00	683.00G	683.70G	685.93E	688.50	690.30E	689.07E	688.32E	687.10G	686.60G	685.90G	30
31	683.10G	.00	683.00G	.00	685.41	.00	690.61E	689.07E	.00	687.20	.00	685.90G	31
MAX	683.70	683.04	683.05	683.70	685.93	689.22	690.70	690.36	689.63	688.30	687.10	686.57	MAX
AVE	683.36	682.99	682.97	683.22	684.47	687.10	690.08	689.49	688.62	687.74	686.77	686.26	AVE
MIN	683.10	682.90	682.90	682.95	683.67	685.51	689.07	688.85	687.86	687.00	686.60	685.90	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1961 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1961

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.90G	685.20G	684.37	683.50G	683.33	685.85	688.30E	687.65	686.10	684.97	683.85	683.60	1
2	685.90G	685.20G	684.30G	683.50G	683.30G	685.97	688.17E	687.70	686.10	684.97	683.80G	683.55	2
3	685.87	685.22	684.24	683.46	683.38	686.20	688.25E	687.60	686.20E	684.95	683.80G	683.60	3
4	685.80G	685.20G	684.20G	683.40G	683.40	686.87E	688.18E	687.56	686.28	684.87	683.80G	683.60	4
5	685.80G	685.10G	684.20G	683.36	683.40G	686.50	688.35E	687.50	686.14	684.87	683.78	683.60	5
6	685.77	685.12	684.21	683.40G	683.50G	686.50	688.30E	687.55	686.11	684.73	683.78	683.55	6
7	685.77	685.10G	684.20	683.30G	683.60G	687.90E	688.21E	687.60	686.19	684.67	683.70	683.50	7
8	685.80G	685.00G	684.17	683.30G	683.68	687.25E	688.30	687.54	686.21	684.67	683.70	683.55	8
9	685.80G	684.90	684.10G	683.20G	683.80G	687.01	688.30	687.45	686.06	684.67	683.72	683.50	9
10	685.81	684.90G	684.10G	683.22	683.90G	687.45E	688.45	687.40	686.01	684.49	683.95	683.50	10
11	685.72	684.88	684.11	683.20G	684.00G	687.57E	688.40	687.30	685.91	684.47	683.75	683.45	11
12	685.82	684.90G	684.10G	683.20G	684.13	687.16	688.38	687.34	685.89	684.47	683.75	683.45	12
13	685.80G	684.80G	684.07	683.21	684.30G	688.15E	688.35	687.30	685.94	684.52	683.72	683.35	13
14	685.80G	684.80	684.00G	683.25G	684.50G	687.56	688.35	687.16	685.69	684.32	683.75	683.35	14
15	685.80G	684.70G	684.00G	683.26	684.63	687.71	688.33	687.24	685.69	684.37	683.70	683.30	15
16	685.70G	684.70G	683.89	683.20G	684.70G	687.76	688.28	687.10	685.73	684.27	683.70	683.40	16
17	685.70G	684.61	683.90G	683.20	684.72	687.79E	688.24	687.10	685.75	684.20	683.73	683.35	17
18	685.70G	684.60G	683.80G	683.20G	684.75	688.00G	688.20	687.00	685.67	684.17	683.73	683.30	18
19	685.60G	684.60G	683.80G	683.20G	684.80G	688.04	688.10	687.00	685.74	683.87	683.68	683.30	19
20	685.60G	684.57	683.77	683.20G	684.80	688.00G	688.16	686.90	685.67	684.07	683.67	683.25	20
21	685.60G	684.50G	683.80G	683.23	684.80G	688.11	688.07	686.90	685.49	684.05	683.65	683.25	21
22	685.50G	684.49	683.70G	683.20G	684.90G	688.10G	688.15	686.80	685.44	684.17	683.65	683.30	22
23	685.50G	684.45G	683.70G	683.30G	684.90	688.10G	688.08	686.85	685.47	684.02	683.65	683.25	23
24	685.50G	684.45	683.70	683.28	684.90G	688.10G	688.21E	686.70	685.17	683.90	683.65	683.30	24
25	685.40G	684.40G	683.60G	683.20G	684.95	688.13E	687.97E	686.65	685.07	683.97	683.70	683.25	25
26	685.40G	684.40G	683.60G	683.30G	685.05	688.30	687.85E	686.60	685.15	683.95	683.60	683.18	26
27	685.40G	684.39	683.64	683.30	685.10G	688.80E	687.80	686.60	685.12	684.07	683.65	683.18	27
28	685.30G	684.40G	683.60G	683.30G	685.20G	688.25	687.80	686.60	685.09	683.92	683.65	683.13	28
29	685.30G	.00	683.61	683.30G	685.35	688.37E	687.74	686.46	685.01	684.07	683.65	683.18	29
30	685.20	.00	683.60G	683.30G	685.55	688.53E	687.74	686.30	684.97	683.87	683.60	683.13	30
31	685.20	.00	683.50G	.00	685.70G	.00	687.70	686.25	.00	683.82	.00	683.08	31
MAX	685.90	685.22	684.37	683.50	685.70	688.80	688.45	687.70	686.28	684.97	683.95	683.60	MAX
AVE	685.64	684.77	683.92	683.28	684.42	687.60	688.15	687.09	685.70	684.34	683.72	683.36	AVE
MIN	685.20	684.39	683.50	683.20	683.30	685.85	687.70	686.25	684.97	683.82	683.60	683.08	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1962 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1962

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.03	682.84	682.92	683.18	683.58	686.23	689.24	690.82	690.17	688.64	686.88	686.08	1
2	683.03	682.89	682.92	683.18	683.68	686.32	689.44	690.72	690.01	688.49	686.88	686.03	2
3	683.08	682.89	682.92	683.18	683.78	686.38	690.04	690.62	689.96	688.24	686.78	685.98	3
4	683.13	682.87	682.92	683.13	683.88	686.58	689.84	690.67	689.91	688.49	686.88	685.98	4
5	682.98	682.86	682.92	683.18	683.98	686.66	689.99	690.67	689.71	688.33	686.83	685.98	5
6	683.08	682.85	682.96	683.18	684.13	687.07E	690.09	690.63	689.66	688.23	686.78	685.98	6
7	683.08	682.86	682.97	683.18	684.32	686.77	690.19	690.63	689.71	688.18	686.78	685.93	7
8	683.03	682.86	682.97	683.18	684.56	687.11E	690.29	690.63	689.81	688.03	686.58	685.88	8
9	683.03	682.89	682.99	683.18	684.76	687.17	690.29	690.68	689.66	687.88	686.48	685.88	9
10	683.03	682.90	682.97	683.18	684.91	687.24E	690.39	690.58	689.46	687.91	686.53	685.81	10
11	683.03	682.87	682.97	683.23	685.02	687.30	690.44	690.54	689.46	687.93	686.58	685.81	11
12	683.03	682.86	682.98	683.18	685.14	687.20E	690.34	690.44	689.41	687.73	686.48	685.76	12
13	683.03	682.89	682.96	683.18	685.21	687.45E	690.44	690.44	689.40	687.58	686.38	685.76	13
14	682.98	682.88	683.03	683.18	685.28	687.62	690.44	690.44	689.35	687.93	686.33	685.76	14
15	682.98	682.84	683.03	683.23	685.29	688.27E	690.49	690.44	689.40	687.73	686.38	685.76	15
16	682.93	682.84	682.98	683.28	685.29	689.00E	690.44	690.35	689.40	687.73	686.38	685.76	16
17	682.98	682.87	683.03	683.23	685.37	688.35E	690.39	690.25	689.25	687.68	686.38	685.71	17
18	682.88	682.88	683.08	683.18	685.40	688.07	690.44	690.25	689.10	687.58	686.28	685.66	18
19	682.93	682.88	683.08	683.23	685.35	688.45E	690.44	690.30	689.10	687.53	686.33	685.66	19
20	682.93	682.87	683.08	683.28	685.36	688.41E	690.49	690.25	689.10	687.48	686.33	685.71	20
21	682.93	682.87	683.08	683.28	685.51	688.54	690.54	690.16	689.05	687.43	686.28	685.66	21
22	682.93	682.89	683.13	683.23	685.62	688.59	690.55	690.31	689.05	687.43	686.18	685.61	22
23	682.98	682.90	683.08	683.28	685.67	688.59	690.50	690.26	688.95	687.33	686.18	685.61	23
24	682.88	682.91	683.13	683.28	685.68	688.74	690.50	690.31	688.89	687.28	686.18	685.56	24
25	682.89	682.90	683.13	683.33	685.73	688.89	690.55	690.31	688.84	687.23	686.18	685.61	25
26	682.90	682.89	683.13	683.33	685.74	688.89	690.60	690.27	688.84	687.18	686.13	685.56	26
27	682.81	682.89	683.13	683.33	685.84	689.04	690.66	690.17	688.74	687.23	686.08	685.56	27
28	682.89	682.90	683.13	683.38	685.85	689.04	690.76	690.17	688.69	687.28	686.08	685.51	28
29	682.87	.00	683.13	683.53	685.90	689.09	690.86	690.12	688.59	687.06	686.08	685.46	29
30	682.84	.00	683.13	683.58	686.01	689.14	690.86	690.12	688.51	686.98	686.13	685.46	30
31	682.84	.00	683.13	.00	686.11	.00	690.86	690.22	.00	686.98	.00	685.46	31
MAX	683.13	682.91	683.13	683.58	686.11	689.14	690.86	690.82	690.17	688.64	686.88	686.08	MAX
AVE	682.97	682.88	683.03	683.25	685.10	687.87	690.37	690.41	689.31	687.70	686.42	685.74	AVE
MIN	682.81	682.84	682.92	683.13	683.58	686.23	689.24	690.12	688.51	686.98	686.08	685.46	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1963 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1963

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.41	684.71	683.85	683.13	683.84	688.15	689.61	689.13	688.55E	685.96E	685.12	684.24	1
2	685.36	684.66	683.79	683.08	684.05	688.26	689.61	689.00E	688.15E	686.41	685.19	684.20	2
3	685.36	684.61	683.73	683.05	684.26	688.32	689.61	688.89E	687.38	685.78E	685.21	684.22	3
4	685.41	684.59	683.79	683.04	684.57	688.42	689.57	688.59E	687.88E	686.09E	685.00	684.15	4
5	685.41	684.59	683.74	683.00	684.83	688.47	689.58	689.00	687.57E	686.03E	684.98	684.22	5
6	685.31	684.54	683.69	683.06	685.08	688.58	689.53	688.75E	687.19E	685.86E	685.01	684.17	6
7	685.31	684.59	683.68	683.01	685.49	688.64	689.53	688.77E	687.13E	685.88E	684.86	684.14	7
8	685.36	684.44	683.63	682.97	685.80	688.74	689.34	688.93	687.28E	685.72E	684.80	684.10	8
9	685.31	684.44	683.58	682.98	686.00	688.69	689.35	688.93E	687.36E	685.74E	684.78	684.08	9
10	685.26	684.43	683.63	682.99	686.21	688.70	689.28	688.83E	687.33E	685.81E	684.75	684.03	10
11	685.16	684.43	683.57	683.00	686.37	688.81	689.73E	688.67E	686.93E	686.03E	684.71	684.06	11
12	685.21	684.28	683.57	682.95	686.48	688.86	689.49E	688.68	686.81E	685.62E	684.63	684.02	12
13	685.16	684.28	683.52	683.01	686.64	688.96	689.37E	688.79E	687.45E	685.70E	684.77	683.97	13
14	685.21	684.23	683.47	682.97	686.74	689.02	689.21E	688.41E	687.45E	685.70E	684.61	683.96	14
15	685.16	684.27	683.47	682.97	686.85	689.08	689.20	688.37E	687.11E	685.66E	684.48	683.96	15
16	685.11	684.22	683.41	682.93	686.91	689.08	689.11E	688.23E	687.06	685.57E	684.67	683.95	16
17	685.06	684.17	683.46	682.94	686.91	689.08	689.39E	688.29E	686.67E	685.67E	684.59	683.90	17
18	685.01	684.17	683.46	682.95	686.97	689.14	689.17	688.25E	686.69E	685.78E	684.56	683.89	18
19	685.11	684.12	683.36	682.96	687.03	689.15	689.10E	688.33	686.65E	685.54E	684.57	683.87	19
20	684.96	684.01	683.36	682.91	687.04	689.35	689.00E	688.13E	686.67E	685.52E	684.50	683.85	20
21	684.91	684.06	683.35	682.92	687.15	689.35	689.31E	688.59E	686.55E	685.16E	684.41	683.83	21
22	684.91	684.01	683.40	682.93	687.30	689.26	689.23	688.35E	686.68E	685.12E	684.33	683.78	22
23	684.91	683.96	683.35	682.98	687.46	689.37	688.77E	688.18E	686.44E	685.63E	684.31	683.76	23
24	684.91	684.01	683.33	683.04	687.37	689.42	688.92E	687.95E	686.69E	685.34E	684.42	683.75	24
25	684.91	683.96	683.30	683.05	687.47	689.47	689.03E	687.97E	686.62E	685.38E	684.36	683.73	25
26	684.81	683.90	683.29	683.11	687.53	689.58	689.18E	688.00	686.56E	685.19E	684.38	683.72	26
27	684.86	683.90	683.29	683.22	687.64	689.54	688.99E	687.87E	686.43E	685.15E	684.39	683.70	27
28	684.81	683.90	683.24	683.27	687.70	689.59	689.07E	687.81E	686.32E	685.19	684.30G	683.68	28
29	684.86	.00	683.24	683.43	687.76	689.59	689.10	687.81E	686.52E	685.10G	684.29	683.67	29
30	684.81	.00	683.14	683.69	687.81	689.55	689.15E	687.59E	686.12E	685.26	684.31	683.66	30
31	684.76	.00	683.13	.00	688.02	.00	689.01E	687.59E	.00	685.20	.00	683.65	31
MAX	685.41	684.71	683.85	683.69	688.02	689.59	689.73	689.13	688.55	686.41	685.21	684.24	MAX
AVE	685.10	684.27	683.48	683.05	686.49	689.01	689.28	688.41	687.01	685.61	684.64	683.93	AVE
MIN	684.76	683.90	683.13	682.91	683.84	688.15	688.77	687.59	686.12	685.10	684.29	683.65	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

1964					LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003								1964

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.62	683.29	683.00	682.94	683.36	685.74	689.74	689.91	690.01	688.61	687.74	686.48	1
2	683.60	683.27	683.00	682.93	683.38	685.78	689.75	690.03	689.94	688.58	687.65	686.43	2
3	683.58	683.28	682.97	682.92	683.45	685.88	689.80	690.03	689.83	688.58	687.57	686.45	3
4	683.60G	683.23	682.94	682.97	683.51	685.93	689.85	690.03	689.81	688.55	687.48	686.46	4
5	683.60G	683.23	682.92	683.00	683.58	685.96	689.91	689.74	689.68	688.52	687.55	686.44	5
6	683.60G	683.25	682.91	682.96	683.68	686.16	689.94	689.93	689.50	688.44	687.56	686.41	6
7	683.60G	683.27	682.90	682.97	683.75	686.37	689.98	689.69	689.62	688.47	687.50	686.41	7
8	683.50G	683.25	682.89	682.96	683.77	686.49	689.99	689.82	689.62	688.42	687.40	686.40	8
9	683.50G	683.23	682.88	682.95	683.83	686.63	689.95	689.81	689.51	688.45	687.37	686.37	9
10	683.50G	683.22	682.90G	682.96	684.43E	686.88	690.00	689.90	689.53	688.48	687.22	686.37	10
11	683.50G	683.22	682.90G	683.01	684.11	686.95	690.01	690.05	689.53	688.37	687.19	686.33	11
12	683.40G	683.18	682.90G	683.02	684.26	687.07	690.00	690.17	689.41	688.32	687.17	686.31	12
13	683.40G	683.18	682.90G	683.02	684.25	687.28	690.00	690.26	689.35	688.25	687.11	686.29	13
14	683.40G	683.14	682.90G	683.01	684.37	687.32	689.91	690.44	689.33	688.29	687.13	686.29	14
15	683.40G	683.12	682.90G	683.04	684.47	687.52	689.79	690.50	689.29	688.31	687.10	686.25	15
16	683.38	683.12	682.90G	683.05	684.49	687.71	689.79	690.48	689.27	688.28	687.00	686.24	16
17	683.36	683.13	682.90G	683.07	684.55	687.84	690.02	690.50	689.22	688.27	686.93	686.20	17
18	683.34	683.11	682.93	683.10	684.67	687.94	690.09	690.50	689.17	688.21	686.89	686.17	18
19	683.32	683.10	682.90	683.11	684.74	688.14	690.04	690.52	689.15	688.25	686.77	686.14	19
20	683.39	683.06	682.94	683.14	684.78	688.31	690.01	690.51	689.12	688.15	686.78	686.10	20
21	683.43	683.09	682.94G	683.07	684.95E	688.31	690.01	690.53	689.08	688.14	686.76	686.08	21
22	683.42	683.07	682.94	683.13	685.00E	688.65	689.96	690.46	689.01	688.07	686.74	686.06	22
23	683.40	683.09	682.92	683.17	685.40E	688.72	690.21	690.37	689.02	688.07	686.67	686.06	23
24	683.41	683.08	682.94	683.14	685.30E	688.96	690.06	690.40	688.95	687.99	686.62	686.02	24
25	683.41	683.06	682.90	683.15	685.17	689.14	690.19	690.42	688.83	687.96	686.64	685.98	25
26	683.41	683.05	682.92	683.20	685.21	689.28	690.20	690.42	688.91	687.83	686.60	685.96	26
27	683.44	683.03	682.90	683.25	685.22	689.38	690.20	690.26	688.80	687.92	686.55	685.91	27
28	683.41	682.99	682.88	683.28	685.30	689.17	690.21	690.20	688.72	688.00	686.51	685.91	28
29	683.37	683.01	682.94	683.25	685.43	689.53	690.22	690.17	688.76	687.88	686.51	685.88	29
30	683.36	.00	682.94G	683.31	685.52	689.65	690.22	690.12	688.66	687.84	686.51	685.85	30
31	683.33	.00	682.95	.00	685.63	.00	690.02	690.08	.00	687.74	.00	685.79	31
MAX	683.62	683.29	683.00	683.31	685.63	689.65	690.22	690.53	690.01	688.61	687.74	686.48	MAX
AVE	683.45	683.15	682.92	683.07	684.50	687.62	690.00	690.20	689.29	688.23	687.04	686.19	AVE
MIN	683.32	682.99	682.88	682.92	683.36	685.74	689.74	689.69	688.66	687.74	686.51	685.79	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1965 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1965

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.76	684.80	684.12	683.51	683.99	686.88	689.50	690.81	689.08	687.63	686.55	685.74	1
2	685.75	684.77	684.05	683.54	684.04	686.91	689.46	690.76	688.99	687.73	686.50	685.75	2
3	685.73	684.73	684.05	683.55	684.21	686.99	689.47	690.76	688.96	687.64	686.49	685.73	3
4	685.71	684.67	684.01	683.54	684.46	687.06	689.55	690.69	688.91	687.65	686.45	685.74	4
5	685.67	684.66	683.97	683.57	684.66	687.21	689.78	690.60	688.87	687.58	686.42	685.70	5
6	685.63	684.61	683.95	683.57	684.93	687.46	689.92	690.59	688.84	687.56	686.46	685.72	6
7	685.61	684.60	683.91	683.55	685.24	687.58	690.00	690.53	688.78	687.55	686.42	685.69	7
8	685.61	684.62	683.87	683.56	685.55	687.78	690.02	690.42	688.67	687.51	686.41	685.68	8
9	685.59	684.62	683.86	683.59	685.76	687.90	690.12	690.39	688.68	687.57	686.36	685.65	9
10	685.54	684.60	683.79	683.59	685.87	688.11	690.14	690.37	688.68	687.49	686.35	685.64	10
11	685.50	684.57	683.78	683.58	685.97	688.18	690.22	690.29	688.67	687.40	686.25	685.61	11
12	685.47	684.59	683.78	683.56	686.05	688.26	690.24	690.30	688.63	687.39	686.17	685.61	12
13	685.39	684.60	683.75	683.56	686.17	688.51	690.28	690.18	688.61	687.39	686.18	685.60	13
14	685.37	684.58	683.72	683.55	686.24	688.71	690.32	690.16	688.53	687.25	686.18	685.54	14
15	685.36	684.55	683.70	683.57	686.27	688.83	690.36	690.08	688.46	687.18	686.16	685.50	15
16	685.31	684.52	683.66	683.56	686.29	688.83	690.36	690.01	688.48	687.38	686.11	685.51	16
17	685.26	684.51	683.64	683.56	686.33	688.93	690.58	689.95	688.44	687.32	686.07	685.49	17
18	685.27	684.46	683.59	683.57	686.40	689.08	690.67	689.91	688.41	687.18	686.03	685.47	18
19	685.18	684.42	683.56	683.58	686.45	689.22	690.94	689.84	688.39	687.19	686.01	685.49	19
20	685.17	684.42	683.50	683.58	686.52	689.26	691.08	689.79	688.32	687.03	685.94	685.46	20
21	685.11	684.38	683.48	683.58	686.56	689.34	691.00	689.71	688.20	687.06	685.89	685.42	21
22	685.06	684.31	683.43	683.58	686.60	689.40	690.96	689.67	688.19	687.01	685.86	685.40	22
23	685.06	684.26	683.48	683.61	686.65	689.44	690.97	689.56	688.21	686.96	685.86	685.38	23
24	685.05	684.23	683.48	683.63	686.61	689.44	691.04	689.50	687.98	687.02	685.84	685.38	24
25	685.02	684.19	683.49	683.66	686.65	689.51	690.98	689.48	687.93	686.96	685.84	685.37	25
26	684.98	684.24	683.49	683.69	686.69	689.49	690.94	689.44	688.03	686.87	685.81	685.35	26
27	684.95	684.22	683.50	683.74	686.75	689.37	690.95	689.37	688.00	686.81	685.78	685.31	27
28	684.90	684.19	683.51	683.83	686.80	689.42	690.96	689.31	687.94	686.81	685.77	685.27	28
29	684.87	.00	683.50	683.90	686.81	689.50	690.96	689.16	687.86	686.73	685.77	685.24	29
30	684.85	.00	683.50	683.96	686.80	689.53	690.92	689.18	687.63	686.64	685.73	685.22	30
31	684.83	.00	683.53	.00	686.84	.00	690.87	689.17	.00	686.56	.00	685.19	31
MAX	685.76	684.80	684.12	683.96	686.84	689.53	691.08	690.81	689.08	687.73	686.55	685.75	MAX
AVE	685.31	684.50	683.70	683.61	685.97	688.54	690.44	690.00	688.45	687.23	686.12	685.51	AVE
MIN	684.83	684.19	683.48	683.51	683.99	686.88	689.46	689.16	687.63	686.56	685.73	685.19	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

1966 LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003 1966

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	685.19	684.34	683.60	682.76	683.17	686.11	688.43	688.89	688.35	687.28	685.98	685.23	1
2	685.17	684.28	683.55	682.77	683.21	686.16	688.40	688.95	688.30	687.30	686.02	685.20	2
3	685.13	684.23	683.47	682.76	683.25	686.29	688.39	688.94	688.27	687.32	685.89	685.15	3
4	685.09	684.21	683.43	682.73	683.33	686.30	688.40	688.90	688.22	687.25	685.80	685.14	4
5	685.08	684.19	683.39	682.73	683.34	686.37	688.43	688.79	688.24	687.24	685.75	685.10	5
6	685.03	684.17	683.36	682.74	683.38	686.46	688.39	688.79	688.23	687.06	685.80	685.09	6
7	685.02	684.14	683.32	682.75	683.43	686.56	688.43	688.80	688.28	687.06	685.76	685.06	7
8	684.98	684.13	683.30	682.73	683.49	686.64	688.45	688.83	688.28	687.08	685.75	685.04	8
9	684.96	684.12	683.26	682.73	683.61	686.71	688.39	688.82	688.20	687.03	685.70	684.99	9
10	684.92	684.10	683.23	682.70	683.75	686.78	688.39	688.74	688.28	686.99	685.71	684.98	10
11	684.91	684.13	683.25	682.71	683.91	686.84	688.32	688.75	688.22	686.89	685.69	684.96	11
12	684.91	684.08	683.23	682.72	684.04	686.93	688.42	688.75	688.21	686.87	685.66	684.90	12
13	684.85	684.08	683.17	682.75	684.13	687.04	688.40	688.80	688.14	686.83	685.66	684.89	13
14	684.83	684.07	683.12	682.76	684.19	687.13	688.46	688.74	688.15	686.89	685.63	684.88	14
15	684.82	684.04	683.10	682.77	684.31	687.23	688.54	688.72	688.03	686.81	685.59	684.84	15
16	684.80	683.99	683.10	682.83	684.48	687.33	688.59	688.70	687.96	686.73	685.58	684.81	16
17	684.80	683.97	683.07	682.84	684.63	687.38	688.56	688.69	688.00	686.61	685.59	684.80	17
18	684.80	683.90	683.05	682.87	684.81	687.52	688.56	688.65	687.97	686.56	685.57	684.77	18
19	684.78	683.86	683.03	682.89	684.94	687.66	688.64	688.62	688.05	686.65	685.53	684.76	19
20	684.73	683.82	683.05	682.90	685.11	687.72	688.74	688.60	688.07	686.51	685.51	684.71	20
21	684.71	683.82	683.02	682.92	685.28	687.88	688.76	688.60	687.94	686.27	685.53	684.69	21
22	684.67	683.79	683.01	682.98	685.43	687.92	688.81	688.61	687.86	686.44	685.50	684.66	22
23	684.64	683.76	682.93	682.99	685.60	687.91	688.81	688.64	687.78	686.40	685.45	684.63	23
24	684.59	683.73	682.90	682.97	685.71	688.03	688.78	688.54	687.68	686.43	685.39	684.60	24
25	684.60	683.71	682.88	682.98	685.78	688.10	688.79	688.55	687.66	686.42	685.45	684.59	25
26	684.58	683.68	682.85	682.96	685.75	688.17	688.82	688.49	687.59	686.24	685.37	684.59	26
27	684.52	683.66	682.86	683.02	685.86	688.21	688.85	688.39	687.47	686.18	685.36	684.52	27
28	684.46	683.64	682.84	683.06	685.92	688.27	688.82	688.34	687.45	686.14	685.33	684.51	28
29	684.42	.00	682.80	683.10	685.97	688.39	688.74	688.35	687.41	686.07	685.32	684.47	29
30	684.40	.00	682.81	683.12	686.05	688.44	688.87	688.29	687.41	686.04	685.28	684.41	30
31	684.36	.00	682.81	.00	686.11	.00	688.89	688.33	.00	685.97	.00	684.41	31
MAX	685.19	684.34	683.60	683.12	686.11	688.44	688.89	688.95	688.35	687.32	686.02	685.23	MAX
AVE	684.80	683.99	683.12	682.85	684.58	687.28	688.59	688.66	687.99	686.70	685.60	684.82	AVE
MIN	684.36	683.64	682.80	682.70	683.17	686.11	688.32	688.29	687.41	685.97	685.28	684.41	MIN
NO.	31.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ATHABASCA AT CRACKINGSTONE POINT 07MC003

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	684.42	683.66	683.10G	682.90G	683.20G	686.85E	690.28	689.83	688.41	686.33	684.91E	684.40G	1
2	684.38	683.63	683.00G	682.90G	683.30G	687.05E	690.34	689.82	688.36	686.41	684.91E	684.40G	2
3	684.34	683.60	683.00G	682.90G	683.50G	687.35E	690.36	689.82	688.36	686.38	685.01E	684.30G	3
4	684.33	683.57	683.00G	682.90G	683.70G	687.50E	690.44	689.80	688.17	686.35	684.96E	684.30G	4
5	684.30	683.55	683.00G	682.90G	684.00G	687.55E	690.54	689.75	688.08	686.30	684.90G	684.30G	5
6	684.27	683.54	683.00G	682.90G	684.30G	687.70E	690.51	689.73	688.07	686.18	684.90G	684.30G	6
7	684.25	683.50	683.00G	682.90G	684.70G	687.65E	690.59	689.61	688.04	686.25	684.90G	684.30G	7
8	684.24	683.45	683.00G	682.90G	685.00G	688.05E	690.54	689.60	687.97	686.22	684.90G	684.30G	8
9	684.21	683.40G	683.02	682.90G	685.30G	688.35E	690.49	689.57	687.91	686.18	684.80G	684.20G	9
10	684.18	683.40G	683.00G	682.90G	685.70G	688.55E	690.49	689.54	687.89	686.08	684.80G	684.20G	10
11	684.19	683.40G	683.00G	682.90G	686.10G	688.65E	690.44	689.49	687.76	686.11	684.80G	684.20G	11
12	684.19	683.40G	683.00G	682.90G	686.30G	688.65E	690.39	689.44	687.68	686.08	684.80G	684.20G	12
13	684.17	683.40G	683.00G	682.90G	686.50G	688.90E	690.38	689.42	687.68	686.06	684.80G	684.10G	13
14	684.15	683.30G	683.00G	682.87	686.70E	688.89	690.23	689.34	687.67	685.61E	684.70G	684.10G	14
15	684.11	683.30G	683.00G	682.90G	686.95E	688.91	690.31	689.21	687.56	685.72E	684.70G	684.10G	15
16	684.08	683.30G	683.00G	682.90G	686.00E	689.00	690.28	689.18	687.50	685.78E	684.73G	684.10G	16
17	684.05	683.30G	683.00G	682.90G	685.05E	689.16	690.21	689.21	687.32	685.56E	684.70G	684.10G	17
18	684.03	683.30G	683.00G	682.90G	684.85E	689.30	690.22	689.13	687.32	686.21E	684.60G	684.07	18
19	683.98	683.30G	683.00G	682.80G	685.30E	689.39	690.18	688.94	687.50	685.56E	684.60G	684.00G	19
20	683.95	683.20G	682.90G	682.80G	685.20E	689.50	690.14	688.90	687.24	685.49E	684.60G	684.00G	20
21	683.95	683.20G	682.90G	682.70G	685.20E	689.54	690.11	688.93	687.20	685.86E	684.60G	684.00G	21
22	683.94	683.20G	682.90G	682.70G	685.50E	689.62	690.05	688.94	686.99	685.97E	684.60G	684.00G	22
23	683.91	683.20G	682.90G	682.80G	685.60E	689.71	690.03	688.86	687.05	685.73E	684.50G	683.90G	23
24	683.88	683.20G	682.90G	682.80G	685.95E	689.81	690.14	688.82	687.01	685.46E	684.50G	683.90G	24
25	683.86	683.20G	682.90G	682.90G	685.95E	689.89	690.17	688.83	686.90	685.56E	684.50G	683.90G	25
26	683.83	683.10G	682.90G	682.90G	686.05E	690.02	689.96	688.81	686.94	685.19E	684.50G	683.90G	26
27	683.79	683.10G	682.90G	683.00G	686.40E	690.03	689.94	688.71	686.82	685.21E	684.50G	683.90G	27
28	683.76	683.10G	682.90G	683.00G	686.65E	690.10	689.83	688.65	686.85	685.19E	684.50G	683.90G	28
29	683.73	.00	682.90G	683.10G	686.75E	690.24	689.79	688.55	686.74	684.98E	684.40G	683.80G	29
30	683.71	.00	682.90G	683.10G	686.65E	690.28	689.79	688.48	686.53	684.96E	684.40G	683.80G	30
31	683.69	.00	.00	.00	686.75E	.00	689.82	688.44	.00	684.91E	684.40G	683.80G	31
MAX	684.42	683.66	683.10	683.10	686.95	690.28	690.59	689.83	688.41	686.41	685.01	684.40	MAX
AVE	684.06	683.35	682.97	682.89	685.45	688.87	690.23	689.20	687.52	685.80	684.69	684.09	AVE
MIN	683.69	683.10	682.90	682.70	683.20	686.85	689.79	688.44	686.53	684.91	684.40	683.80	MIN
NO.	31.	28.	30.	30.	31.	30.	31.	31.	30.	31.	31.	31.	DAY

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	683.60G	683.20G	682.85G	682.86G	683.19	683.80	684.61	684.63	683.82	682.83E	682.66	682.61	1
2	683.70G	683.20G	682.85G	682.87	683.23	683.83	684.60	684.58	683.72	682.83E	682.61	682.58	2
3	683.70G	683.20G	682.85G	682.88G	683.29	683.90	684.61	684.53	683.74	682.97E	682.59	682.62	3
4	683.70G	683.20G	682.85G	682.89G	683.32	683.96	684.53	684.53	683.74	682.88E	682.67	682.58	4
5	683.70G	683.20G	682.85G	682.90G	683.41	683.96	684.42	684.46	683.74	682.61E	682.56	682.55	5
6	683.70G	683.20G	682.85G	682.91G	683.45	683.93	684.58	684.47	683.67	683.02E	682.59	682.52	6
7	683.60G	683.20G	682.85G	682.92G	683.52	683.96	684.52	684.48	683.65	682.96E	682.58	682.53	7
8	683.60G	683.10G	682.85G	682.93G	683.58	683.98	684.58	684.38	683.64	683.09E	682.60	682.57	8
9	683.60G	683.10G	682.85G	682.94G	683.60	684.01	684.61	684.33	683.63	683.05E	682.65	682.53	9
10	683.60G	683.10G	682.85G	682.95G	683.61	683.98	684.51	684.36	683.60	683.08E	682.59	682.52	10
11	683.60G	683.10G	682.85G	682.96G	683.65	683.99	684.53	684.30	683.58	682.83E	682.59	682.51	11
12	683.50G	683.10G	682.85G	682.97G	683.69	683.97	684.47	684.22	683.54	683.21E	682.56	682.53	12
13	683.50G	683.10G	682.85G	682.97G	683.70	684.02	684.58	684.30	683.62	682.81E	682.62	682.48	13
14	683.50G	683.10G	682.85G	682.98G	683.71	684.07	684.56	684.32	683.52	682.65E	682.64	682.52	14
15	683.50G	683.00G	682.85G	682.98G	683.70	684.07	684.59	684.23	683.37	682.76E	682.58	682.53	15
16	683.50G	683.00G	682.85G	682.99G	683.73	684.09	684.66	684.24	683.35	682.39E	682.56	682.51	16
17	683.45	683.00G	682.85G	682.99G	683.74	684.08	684.68	684.24	683.27	682.60E	682.56	682.54	17
18	683.40G	683.00G	682.85G	682.99	683.74	684.07	684.70	684.23	683.16	683.37E	682.59	682.50	18
19	683.40G	683.00G	682.85G	683.01	683.74	684.11	684.70	684.17	683.16	682.92	682.64	682.52	19
20	683.40G	683.00G	682.85G	683.02	683.75	684.19	684.73	684.18	683.10	682.65E	682.68	682.49	20
21	683.40G	683.00G	682.85G	683.04	683.75	684.25	684.72	684.17	683.05	682.83E	682.65	682.50	21
22	683.40G	682.90G	682.85G	683.04	683.73	684.22	684.75	684.16	683.00	682.73	682.68	682.47	22
23	683.40G	682.90G	682.85G	683.02	683.71	684.26	684.76	684.15	683.04	682.67	682.67	682.43	23
24	683.40G	682.90G	682.85G	683.00	683.75	684.33	684.86	684.13	683.03	682.78	682.62	682.41	24
25	683.30G	682.90G	682.85G	683.03	683.76	684.42	684.81	684.08	683.05	682.70	682.65	682.41	25
26	683.30G	682.90G	682.85G	683.02	683.78	684.48	684.78	684.06	682.77E	682.61	682.69	682.42	26
27	683.30G	682.90G	682.85G	683.05	683.79	684.53	684.74	684.00	683.07E	682.65	682.58	682.41	27
28	683.30G	682.90G	682.85G	683.08	683.78	684.48	684.69	683.96	682.63E	682.70	682.64	682.37	28
29	683.30G	682.84	682.85G	683.11	683.76	684.40	684.66	683.88	682.52E	682.65	682.69	682.38	29
30	683.30G	.00	682.85G	683.14	683.79	684.54	684.65	683.86	682.58E	682.72	682.70	682.37	30
31	683.30G	.00	682.85G	.00	683.80	.00	684.64	683.82	.00	682.71	.00	682.41	31
MAX	683.80	683.20	682.85	683.14	683.80	684.54	684.86	684.63	683.82	683.37	682.70	682.62	MAX
AVE	683.49	683.04	682.85	682.98	683.64	684.13	684.64	684.24	683.31	682.81	682.62	682.49	AVE
MIN	683.30	682.84	682.85	682.86	683.19	683.80	684.42	683.82	682.52	682.39	682.56	682.37	MIN
NO.	31.	29.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

12 AUG 1970

LAKE ELEVATIONS IN FEET - 1968 G.S.C. DATUM REV.1

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	682.37	682.50G	682.70G	682.90G	685.20G	685.77E	684.97E	684.13	683.36	682.59	682.05	681.88	1
2	682.38	682.50G	682.70G	682.90G	685.22G	685.63E	685.05E	684.11	683.34	682.57	682.03	681.80G	2
3	682.35	682.50G	682.70G	682.90G	685.25G	685.68E	685.75E	684.04	683.31	682.56	682.01G	681.80G	3
4	682.37	682.50G	682.70G	682.90G	685.28G	685.79E	685.71E	683.99	683.28	682.56	682.00	681.79	4
5	682.39	682.50G	682.70G	682.90G	685.30G	685.74E	685.30E	683.95	683.25	682.57	682.00G	681.75G	5
6	682.34	682.50G	682.70G	683.00G	685.33G	685.94E	685.01E	683.90	683.22	682.52	681.99G	681.75G	6
7	682.40G	682.55	682.80G	683.00G	685.36G	685.60E	684.89E	683.84	683.19	682.52	681.99G	681.75G	7
8	682.40G	682.60G	682.80G	683.00G	685.40G	685.62E	684.94E	683.78	683.14	682.47	681.98G	681.75G	8
9	682.40G	682.60G	682.80G	683.00G	685.44G	686.16E	684.80E	683.78	683.09	682.41	681.98	681.72	9
10	682.40G	682.60G	682.80G	683.00G	685.47G	686.15E	684.98E	683.76	683.06	682.42	682.00	681.72	10
11	682.40G	682.60G	682.80G	683.00G	685.50G	685.91E	684.84E	683.74	683.04	682.45	682.00G	681.72	11
12	682.40G	682.60G	682.80G	683.00G	685.55G	685.68E	684.19E	683.71	682.83	682.50	681.99G	681.71	12
13	682.40G	682.60G	682.80G	683.00G	685.60G	685.66E	684.20E	683.69	682.65	682.48	681.98G	681.72G	13
14	682.40G	682.60G	682.80G	683.00G	685.70G	685.56E	684.24E	683.67	682.65	682.38	681.97	681.72G	14
15	682.40G	682.60G	682.80G	683.00G	685.80G	685.30E	684.35E	683.62	682.77	682.49	681.91	681.73	15
16	682.40G	682.60G	682.80G	683.05	685.85E	685.75E	684.63E	683.61	682.81	682.47	681.90	681.76	16
17	682.40G	682.60G	682.80G	683.30G	685.94E	685.50E	684.63	683.61	682.82	682.47	681.90G	681.75	17
18	682.40G	682.60G	682.80G	683.60G	686.10E	685.90E	684.60	683.60	682.72	682.45	681.91	681.74	18
19	682.40G	682.60G	682.80G	683.90G	685.82E	685.43E	684.60	683.59	682.61	682.08E	681.91	681.73G	19
20	682.40G	682.60G	682.80G	684.20G	685.83E	685.09E	684.54	683.58	682.73	682.23E	681.90G	681.73G	20
21	682.40G	682.60G	682.90G	684.50G	685.88E	685.48E	684.51	683.57	682.71	682.31	681.89	681.72G	21
22	682.40G	682.70G	682.90G	684.80G	685.82E	685.82E	684.51	683.56	682.69	682.19E	681.90G	681.72G	22
23	682.40G	682.70G	682.90G	685.03E	685.95E	685.53E	684.50	683.55	682.69	681.69E	681.90	681.71	23
24	682.40G	682.70G	682.90G	684.92E	686.13E	685.34	684.41	683.52	682.66	681.20E	681.92	681.71	24
25	682.40G	682.70G	682.90G	685.13E	685.86E	685.44E	684.38	683.46	682.66	681.71G	681.93G	681.70	25
26	682.40G	682.70G	682.90G	685.24E	685.94E	685.28E	684.36	683.46	682.65	682.22	681.92G	681.70G	26
27	682.40G	682.70G	682.92	685.26E	685.69	685.27E	684.36	683.46	682.64	682.17	681.91	681.70G	27
28	682.40G	682.70G	682.90G	685.14E	685.85E	685.37E	684.31	683.46	682.63	682.12	681.39E	681.69G	28
29	682.40G	.00	682.90G	685.10E	685.97E	685.23E	684.26	683.46	682.63	682.11G	681.15E	681.69	29
30	682.40G	.00	682.90G	685.18E	685.90E	684.88E	684.19	683.44	682.61	682.09	681.27E	681.69	30
31	.00	.00	682.90G	.00	685.72E	.00	684.17	683.43	.00	682.07G	.00	681.69G	31
MAX	682.40	682.70	682.92	685.26	686.13	686.16	685.75	684.13	683.36	682.59	682.05	681.88	MAX
AVE	682.39	682.60	682.82	683.76	685.67	685.58	684.65	683.68	682.88	682.29	681.89	681.73	AVE
MIN	682.34	682.50	682.70	682.90	685.20	684.88	684.17	683.43	682.61	681.20	681.15	681.69	MIN
NO.	30.	28.	31.	30.	31.	30.	31.	31.	30.	31.	30.	31.	DAY

LAKE ATHABASCA NEAR CRACKINGSTONE POINT - STATION NO. 07MC003

DAILY WATER LEVEL IN FEET FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	684.18	684.55	683.72	682.79	---	681.72	1
2	---	---	---	---	---	---	684.21	684.51	683.54	682.72	---	681.71	2
3	---	---	---	---	---	---	684.26	684.50	683.49	682.65	---	681.72	3
4	---	---	---	---	---	684.07	684.32	684.47	683.57	682.65	681.96	681.75	4
5	---	681.66	---	---	---	684.10	684.42	684.40	683.65	682.63	681.86	681.74	5
6	---	---	---	---	---	684.06	684.48	684.43	683.63	682.67	681.91	681.72	6
7	---	---	---	---	---	684.02	684.54	684.37	683.65	682.64	681.91	681.76	7
8	---	---	---	---	---	683.97	684.63	684.47	683.59	682.60	681.92	681.76	8
9	---	---	---	---	---	684.03	684.61	684.52	683.51	682.61	681.87	681.75	9
10	---	---	---	---	---	684.02	684.72	684.53	683.39	682.55	681.88	681.75	10
11	---	---	---	---	---	684.06	684.68	684.49	683.31	682.50	681.83	681.75	11
12	---	---	---	---	---	684.15	684.79	684.39	683.35	682.44	681.82	681.75	12
13	---	---	---	---	---	684.13	684.81	684.32	683.35	682.44	681.85	681.74	13
14	---	---	---	---	---	684.20	684.82	684.28	683.36	682.42	681.85	681.75	14
15	---	---	---	---	---	684.25	684.84	684.26	683.25	682.38	681.83	681.75	15
16	---	---	---	---	---	684.22	684.75	684.28	683.21	682.41	681.78	681.78	16
17	---	---	---	---	---	684.20	684.82	684.30	683.13	---	681.82	681.77	17
18	---	---	---	---	---	684.28	684.82	684.18	683.09	---	681.77	681.78	18
19	---	---	---	---	---	684.28	684.87	684.11	683.11	---	681.76	681.77	19
20	---	---	---	---	---	684.29	684.90	684.08	683.09	---	681.73	681.75	20
21	---	---	---	---	---	684.24	684.87	684.09	683.06	---	681.73	681.73	21
22	---	---	---	---	---	684.21	684.90	684.05	683.01	---	681.77	681.75	22
23	---	---	---	---	---	684.16	684.85	683.98	682.94	---	681.77	681.76	23
24	---	---	---	---	---	684.18	684.77	683.99	682.88	---	681.73	681.77	24
25	---	---	682.18	---	---	684.28	684.77	683.91	682.94	---	681.72	681.80	25
26	---	---	---	---	---	684.30	684.74	683.86	682.86	---	681.73	681.77	26
27	---	---	---	---	---	684.29	684.72	683.94	682.83	---	681.81	681.74	27
28	---	---	---	---	---	684.21	684.69	683.92	682.83	---	681.76	681.77	28
29	---		---	---	---	684.11	684.67	683.86	682.80	---	681.83	681.75	29
30	---		---	---	---	684.16	684.68	683.84	682.85	---	681.77	681.76	30
31	---		---		---		684.74	683.84		---		681.77	31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 22 55 N
LONG 108 52 50 W

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

LAKE ATHABASCA NEAR CRACKINGSTONE POINT - STATION NO. 07MC003

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	681.96	682.22	682.52	683.17	683.77	684.90	686.52	685.20	683.81	682.68	682.39	1
2	---	681.95	682.21	682.54	---	683.81	684.94	686.52	685.02	683.74	682.67	682.32	2
3	---	681.98	---	682.58	---	683.70	684.98	686.53	685.05	683.73	682.70	682.40	3
4	---	682.00	---	682.57	683.57	683.71	685.07	686.51	685.11	683.68	682.63	682.40	4
5	---	682.03	---	682.60	---	683.67	685.13	686.39	685.05	683.65	682.64	682.38	5
6	681.78	682.02	---	682.58	683.76	683.67	685.1[illegible]	686.45	685.06	683.65	682.63	682.36	6
7	681.81	682.00	---	682.60	---	683.56	685.16	686.38	685.01	683.67	682.59	682.35	7
8	681.82	682.03	---	682.63	---	683.55	685.26	686.39	684.97	683.58	682.60	682.32	8
9	681.83	682.05	---	682.57	---	683.98	685.31	686.34	684.90	683.60	682.55	682.32	9
10	681.84	682.00	---	682.58	683.89	684.05	685.33	686.29	684.82	683.53	682.50	682.35	10
11	681.83	681.99	---	---	---	684.05	685.38	686.25	684.79	683.41	682.58	682.35	11
12	681.81	681.99	---	---	683.79	684.04	685.47	686.14	684.82	683.48	682.52	682.33	12
13	681.83	682.05	---	---	---	684.06	685.47	686.26	684.83	683.32	682.51	682.29	13
14	681.85	682.07	---	---	---	684.00	685.51	686.09	684.66	683.27	682.52	682.29	14
15	681.81	682.08	---	---	683.90	683.95	685.50	685.95	684.55	683.27	682.55	682.33	15
16	681.79	682.11	682.40	---	---	684.03	685.58	685.95	684.55	683.30	682.48	682.27	16
17	681.84	682.10	682.41	---	683.95	684.12	685.76	685.92	684.66	683.27	682.49	682.29	17
18	681.83	682.10	682.43	---	---	684.15	685.92	685.89	684.51	683.27	682.42	682.29	18
19	681.84	682.13	682.43	---	---	684.19	686.10	685.84	684.39	683.22	682.38	682.26	19
20	681.89	682.15	682.43	---	683.97	684.26	686.22	685.73	684.31	683.18	682.39	682.29	20
21	681.91	682.17	682.44	---	---	684.31	686.30	685.68	684.35	683.18	682.38	682.25	21
22	681.93	682.17	682.45	---	683.98	684.36	686.35	685.72	684.25	683.12	682.39	682.23	22
23	681.92	682.20	682.46	---	---	684.40	686.39	685.78	684.15	683.10	682.38	682.21	23
24	681.90	682.20	682.47	---	684.00	684.48	686.52	685.70	683.96	683.05	682.35	682.19	24
25	681.92	682.23	682.47	---	---	684.54	686.60	685.65	683.80	683.09	682.39	682.19	25
26	681.91	682.22	682.46	---	---	684.32	686.59	685.64	683.91	682.93	682.39	682.18	26
27	681.92	682.23	682.50	---	---	684.59	686.60	685.55	683.94	682.84	682.36	682.17	27
28	681.92	682.22	682.52	---	---	684.79	686.58	685.50	684.00	682.87	682.35	---	28
29	681.93		682.50	---	---	684.83	686.63	685.46	683.90	682.93	682.39	---	29
30	681.97		682.52	---	---	684.85	686.58	685.40	683.87	682.85	682.40	---	30
31	681.98		682.54		---		686.56	685.33		682.78		---	31

SUMMARY FOR THE YEAR 1971
MAXIMUM DAILY WATER LEVEL, 686.63 FT ON JUL 29
MINIMUM DAILY WATER LEVEL, 681.78 FT ON JAN 6

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 22 55 N
LONG 108 52 50 W

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

Lake Athabasca near Crackingstone Point   Station No. 07MC003

Daily Elevations or Gauge Heights in Feet for the Year 1972

Day	January	February	March	April	May	June	July	August	September	October	November	December
1					682.79	686.37	688.12	688.20	686.92	685.35	684.21	
2					683.08	686.35	688.27	688.07	686.74	685.38	684.22	
3						686.36	688.22	688.04E	686.78	685.39	684.24	
4					683.10	686.39	688.23E	688.01E	686.67		684.15	
5					683.21	686.29	688.24E	687.98E	686.61	685.13	684.15	
6					683.39	686.42	688.25E	687.95E	686.61	685.16	684.11	
7					683.64		688.26E	687.92E	686.53	685.11	684.13	
8					683.82	686.30	688.27E	687.89E	686.45	685.04	684.14	
9	682.00				684.04	686.49	688.28E	687.86E	686.20	684.88	684.12	
10					684.29	686.48	688.29E	687.83E	686.35	684.94	684.07	
11					684.56	686.50	688.30E	687.80E	686.37	684.98	684.07	
12					684.67	686.49	688.31E	687.77E	686.27	684.94	684.07	
13					685.02	686.46	688.32E	687.74E	687.19	684.86	684.05	
14						868.56	688.33E	687.71E	686.10	684.79	684.05	
15					685.09	686.55	688.34E	687.68E	686.06	684.65	684.09	
16			682.06		685.18	686.54	688.35E	687.65E	685.98	684.65	684.05	
17					685.35	686.54	688.36E	687.62E	685.94	684.67	684.03	
18					685.44	868.79	688.37E	687.60		684.69	684.06	
19					685.56	687.07	688.38E	687.55		684.62	684.09	
20					685.63	687.28	688.39E	687.60		684.60	684.08	
21					685.75	687.34	688.41E	687.58	685.49	684.54	684.10	
22					685.84	687.29	688.43E	687.55	685.57	684.51	684.12	
23					685.90	687.50	688.45E	687.47E	685.56	684.54	684.15	
24					685.92	687.58	688.46	687.40		684.49	684.12	
25					686.01	687.78	688.35	687.37E	685.42	684.32	684.15	
26					686.02	687.84	688.44	687.35	685.42	684.37	684.12	
27					686.06	688.02	688.43	687.17	685.30	684.40	684.16	
28					686.13	688.18	688.28	687.35	685.27	684.37	684.15	
29				682.72	686.10	688.16E	688.22	687.16E	685.25	684.40		
30				682.77	686.16	688.14E	688.24	686.96	685.16	684.43		
31					686.17		688.22E	686.84		684.29		
					684.96	686.96	688.31	687.63	686.04	684.74	684.11	

E - Estimated

SECTION B

SECTION B

FACTORS INFLUENCING WATER LEVELS

J. R. CARD
HYDROLOGY BRANCH
ALBERTA ENVIRONMENT
EDMONTON 1972

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FACTORS INFLUENCING WATER LEVELS

All lakes are a volume of water held in a natural depression in the earth's surface. The quantity of water in a lake, and hence its surface elevation, is governed by how much water is being added to the lake and how much is being removed.

There are three major ways in which water is added to a lake. The largest source is usually from run off over the surface of the ground by way of rivers and streams. The second may be by replenishment due to a subsurface flow of water into the lake. The third is by precipitation which falls directly on the surface of the lake.

Water can be removed from a lake in three ways as well. Often the major quantity of water will be removed by an outflowing river or stream. Removal of water by a subsurface flow of water away from the lake may also occur. The third route which water may take is by direct evaporation from the lake surface, and by consumption by plant life in or near the lake.

The lakes of the Delta not only respond to these influences but also many lakes in the Delta can receive water by innundation from other nearby lakes or rivers. In fact large areas of the Delta can be flooded during high water levels such that several lakes may be joined to form a larger body of water.

The level of the water surface of a river is primarily determined by the volume of water flowing in the channel, and by obstructions in the channel such as ice jams, log jams, and beaver dams. Upstream of obstructions the river is raised in accordance with the volume of water flowing and the degree of obstruction being created. In the reach of a river which is immediately upstream of a lake, the level of the lake and the river flow determine the water level in the river.

The rivers within the Peace-Athabasca Delta are subject to all of the foregoing influences as well as being subject to varying water levels due to their very slight surface slope. The water level at each end of a Delta river determines the rate of flow, the direction of flow and the level of the river itself.

CLIMATE FACTORS

Although the main source of water is from outside the immediate Delta area, any shortage in this supply brings into sharp focus the significance of the local climate. Four climate factors have a bearing on the water levels in the Delta. These are precipitation, evaporation, temperature, and wind.

Average annual precipitation at Fort Chipewyan is 12.6 inches (10 year mean). Winter precipitation from November to April averages 4.3 inches, while rainfall during the remainder of the year averages 8.3 inches.

Evaporation from the water surfaces of the Delta represents a significant loss of moisture and hence is an important part of the total water balance. The estimated mean value of annual evaporation for lakes of the region is 16 inches. It is unlikely that this value may be directly applied to Lake Athabasca due to its large size, but the value is probably applicable to the smaller lakes of the Delta. Direct observations of evaporation were made in 1970 and 1971 during the months of June, July and August using a Class A Evaporation pan located on the east side of Mamawi Lake. The indicated net lake evaporation for the 3 month period in 1970 was 6.7 inches, and in 1971 was 4.4 inches. Calculations based upon water level changes in small basins in the Delta during 1971 indicate that 18 inches of water were lost be evaporation, transpiration, and seepage during the 6 month period May to October. Inasmuch as evaporation is usually greater than precipitation during the ice free period of the year, it follows that a persistent reduction in water levels will occur in most basins unless they

are refilled by flooding.

Temperature, particularly during the winter, affects the water balance by determining local rates of snowmelt and spring runoff, and influencing the production of ice in the rivers and lakes. It now appears that several lakes in the Delta are saved from being drained during the winter because their outlets freeze solidly and prevent or reduce outflow. Such appears to be the case with Lakes Claire, Mamawi, Richardson, and many other smaller lakes. Even the level of Lake Athabasca is affected by the formation of an ice sheet which forms in the shallow west end of the lake and restricts the outflow. This condition can lead to the establishment of a physical control point for outflow somewhere in the vicinity of Pine Island just east of Fort Chiepwyan. An outflow channel then develops in the lake at Fort Chipewyan where winter water levels were observed to be at elevation 676 in March of 1971, some 6 feet lower than in the main body of the lake. This causes water levels in Riviere des Rochers, Chenal des Quatre Fourches and other adjoining channels to recede to similar levels during the winter. This phenomenon has not yet been completely documented but is the subject of further investigations.

The date of freeze-up in the Delta varies depending upon the location being considered: the shallow basins are the first to be ice covered and the rivers the last. However, using observation of ice formation in Lake AThabasca at Fort Chipewyan, the average start of freeze-up is October 25. Similarly, the average date of the start of break-up at Fort Chipewyan is May 20. The large lakes of the area, however, may still contain ice as late as mid-June. The frost-free period in relation to the growing season of the Delta is approximately 90 days. The average date of last frost at Fort Chipewyan is June 7, and the average date of first frost in the fall is September 5.

Wind is an important factor to water levels in the Delta due to the seiche effect which occurs on Lake Athabasca with strong southwest or northeast winds.

From an examination of lake levels and wind data at Fort Chipewyan and Uranium City, for May to July 1970, it appears there is a significant relationship between the wind and the levels of Lake Athabasca. While three months is not a lengthy period of record, it was thought some clarification could be made, to visual indications, that the wind was affecting the lake level.

There were 23 days during this period when the lake level had pronounced fluctuation of 1/2 - 3 feet. The wind action for the same period was compared to the gauge height recordings for the lake level, and the results were:

- W.S.W., W., N. and N.E. winds tend to have the greatest effect on the lake level. (These winds occurred on 19 out of the 23 days.)
- From these winds, the W.S.W. and W. winds caused the highest and most frequent fluctuations. These winds had an overall tendency to cause the lake level to drop. (These winds occurred on 11 out of the 19 days.)
- The N. and N.E. winds have the reverse effect, by causing the lake level to rise. (These winds were found on 8 out of the 19 days.)
- The highest fluctuation was recorded on July 8th. During the 24 hour period, the lake level decreased 2.8 feet over the first 14 hours and then increased again 2.4 feet in the remaining 10 hours. For the same 24 hour period, the wind was from the W.S.W. at an average velocity of 10 mph and a maximum velocity of 22 mph.

To illustrate the effect of the N.E. and S.W. winds, the lake levels for four different days were plotted hourly with the wind action for the same period.

Using the data from the four days plotted and assuming the wind was the determining factor in the changing lake levels, it was found that an average wind speed of 13 mph was required to cause a 1 foot fluctuation. Under the same assumption, the wind would have to blow approximately 6 hours

at 13 mph to make a 1 foot fluctuation.

A further examination of data was done, to indicate a possible oscillating movement of the lake surface, which would also effect the lake level.

From the lake levels at Fort Chipewyan, a period was chosen where little change occurred in gauge height. For a nine day period from June 9 - 17, with average wind conditions, there appeared to be a gradual increase and decrease in the lake level on each day. These minor fluctuations were recorded and an average of 7 hours was calculated for the time between peaks. The equation:

$$Tn = \frac{1}{n} \times \frac{2L}{gd}$$

For determining the period for lake seiches, was also applied.

Where: Tn = period of the seiche
L = length of water body (130 miles)
n = no. of nodes
d = mean depth (85 feet)
g = acceleration of gravity

The results gave a period of 7.28 hours, comparable to the 7 hour average found during the nine day period.

LAKE ATHABASCA

Lake Athabasca with its 3,000 square mile surface area is the key to water levels in the Peace-Athabasca Delta. In spite of its large size, Lake Athabasca undergoes a considerable annual fluctuation in water level. These changes in water level can be as much as 10 feet in one year, but average about 5.5 feet. The most dramatic change in levels occurs when the lake rises from its winter minimum of 682.5 feet to its midsummer peak of 688.0. The volume of water required to raise Lake Athabasca the 5.5 feet is approximately 11 million acre feet.

INFLOW

Lake Athabasca has a watershed of 112,000 square miles. The major tributary is the Athabasca River with a drainage area of 61,300 square miles. This river rises in the Rocky Mountains and hence its flow is characteristic of all mountain rivers in that it has a high summer discharge and low winter flow. The Fond du Lac River is the second most important tributary and has a gross drainage area of 33,200 square miles upstream of the village of Fond du Lac. It has its headwaters in the Canadian Shield area of northern Saskatchewan and its watershed contains many lakes which are typical of the Shield. Consequently this river is characterized by relatively stable discharges with little change from season to season.

The largest lake in the Fond du Lac watershed is Wollaston Lake and it is worthy of note since it has two outlets. One outlet is the Fond du Lac River which flows to Lake Athabasca and the other outlet is the Cochrane River which is a part of the Churchill River system draining into Hudson Bay. Preliminary investigations (Davis 1970) indicate that the total outflow from Wollaston Lake is divided so that approximately 90% of the water goes into the Cochrane River, while the remaining 10% flows into the Fond du Lac. Since the lake has a total drainage area of 6,200 square miles, only some 620 square miles are considered to be contributing to Lake Athabasca.

The Lake Athabasca watershed, other than these two major rivers, is composed of 6,500 square miles draining into the south side of the lake, 2,800 square miles drainage from the north, and 8,100 square miles which drain into Lakes Claire and Mamawi at the west end of the Lake. These areas are characterized by relatively low runoff but they do exhibit a high variability from year to year in the total volume of runoff.

Another source of water for Lake Athabasca is the Peace River. This river, although not a direct tributary to the lake, frequently discharged some of its water into the lake during periods of high river flows and as a result of ice jams which raise the river high enough to flow into the lake. Traditionally Peace River water flowed into Lake Athabasca during the spring and summer whenever the water level in the river was higher than the lake. The volume of water added to the lake from the Peace averaged one million acre feet annually in the 1960 to 1967 period.

OUTFLOW

Outflow from Lake Athabasca is by way of two channels, the Riviere des Rochers and the Chenal des Quatre Fourches. A third channel, the Revillon Coupe is a branch of Riviere des Rochers and is relatively small in comparison to the other two. All three rivers join Lake Athabasca to the Peace River. The flow of water in these channels is determined by the relative difference of water levels in the Peace and in the lake. The higher Lake Athabasca is in relation to the Peace River, the greater the outflow will be. Conversely, higher Peace River levels create a southward flow of water into Lake Athabasca. When the levels of both are equal then the lake is effectively dammed and there is neither inflow nor outflow. The Slave River begins at the confluence of the Peace River and the Riviere des Rochers and its flow is a function of the discharge in the Peace and the outflow from Lake Athabasca.

SECTION C

SECTION C

MATHEMATICAL SIMULATION OF THE SYSTEM

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Edmonton
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Alberta Environment
Edmonton
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MATHEMATICAL SIMULATION OF THE SYSTEM

THE HYDRAULIC NETWORK

The channels linking Lake Athabasca, the delta lakes and the Peace River form an intricate hydraulic network. The flows in the interconnecting channels respond to the Peace River flow and Lake Athabasca level and, although the predominant flow is towards the Peace River, reversed flow occurs at high stages of the Peace River.

The degree of complexity of the system to be represented by the simulation model must be limited to some extent to simplify the mathematical solution of the system and to be consistent with the data which are available to adequately describe the system hydraulics. At the same time however sufficient complexity must be retained in the model so as not to reduce excessively the accuracy and the reliability of the simulation.

The network system selected for simulation in this study consists of the Riviere des Rochers, Chenal de Quatre Fourches, Revillon Coupe and the reach of the Peace River between the Quatre Fourches and Rochers channels. The delta lakes and their interconnecting channels were not included as individual entities but were combined with Lake Athabasca and treated as a single water body.

As illustrated in Figure C-1 and Figure C-2, the simulation model was developed with two options; Option #1 without the Revillon Coupe considered and Option #2 with the Revillon Coupe considered. Option #1 considerably simplified the solution of the flow functions of the network.

AVAILABLE HYDRAULIC DATA

All available data were assembled and reviewed in order to establish the required flow function for each of the network channels. Tabulations of

the data are presented in Tables C-1 to C-4. Where published records are available they were used as the data source. Records for 1960 were obtained from the Water Survey of Canada, Report No, 11, entitled "Peace River investigation, 1960." Some data, as indicated in the tabulations, were not included in the regression analyses for the various flow functions because the data set was either incomplete or at variance with the other data.

HYDRAULIC FUNCTIONS

Regression Analysis for Flow Functions

Each set of data included in the regression data for analysis of the network channel flow functions consisted of simultaneous upstream and downstream stages together with a discharge value. In order to force the regression equation into a form equivalent to Manning's equation, log transforms were applied of the form:

$$\text{Log } (H_1 + H_2)/2 \qquad \text{and}$$

$$\text{Log } Q/(H_1 - H_2)^{0.5}$$

The generalized channel flow functions are of the form:

$$Q = K\left[\frac{H_1 + H_2}{2}\right]^X \left[H_1 - H_2\right]^{0.5}$$

where Q = channel discharge in 1000 cfs.

H_1= upstream stage in feet above channel datum

H_2= downstream stage in feet above channel datum

Values of channel datum are listed in Table C-5 as E (base).

The channel flow functions together with the transformed data are shown on Figures C-3 to C-8 for the various channels. To test the reasonableness of each flow function, Manning's n was computed for a range of stages, based on average channel conveyance factors as determined from measured cross-sections. The resulting values of n together with the values of the coefficients and exponent for each channel of the network are shown in Table C-5 and Table C-6.

At the Peace-Slave-Rochers confluence a direct stage/discharge relationship was formulated as:

$$H_1 = K(Q)^x$$

The values of the coefficient and exponent determined from the regression analysis for this relationship are also included in Table C-5. The adequacy of this stage/discharge relationship was checked by comparing it with relationships for the Peace River at Peace Point and the Slave River at Fitzgerald (obtained from the Water Survey of Canada) as shown in Figure C-9.

Critical Depth Functions

The nature of the developed flow functions for the network channels is such that after a certain head difference in the channel is exceeded a further increase in head results in a decrease in discharge. To exclude this unrealistic condition from the simulation, critical depth relationships for each channel were developed. The generalized form of the critical depth functions are:

$$Hc = Kc\ (Q)^y \qquad \text{and}$$

$$Hc = Cc\ (H_1)$$

where Hc = critical stage in feet above channel datum,

H_1 = upstream stage in feet above channel datum, and

Q = channel discharge in 1000 cfs.

Values of these coefficients and exponents for each channel are included in Table C-5.

Once the downstream depth in the channel becomes less than critical, channel discharge becomes essentially a function of the upstream stage only.

Weir Equations

To permit inclusion of various control structures in the simulation of the Peace-Athabasca delta channel flows, expressions for the hydraulic conditions imposed by the structures were developed for both the free and submerged discharge conditions. The generalized form of the control structure hydraulic functions are:

$$Q = C_f \, W\left[H_1 - H\,(\text{crest})\right]^{N_f} \qquad \text{(free discharge)}$$

$$Q - C_s \, W\left[-\log S\right]^{N_s}\left[H_1 - H_2\right]^{N_f} \qquad \text{(submerged discharge)}$$

where Q = discharge in 1000 cfs.

H_1= upstream stage in feet above channel datum

H(crest) = crest height in feet above channel datum

H_2= downstream stage in feet above channel datum

W = crest width in feet

$$S = \left[\frac{H_2 - H(\text{crest})}{H_1 - H(\text{crest})}\right] = \text{degree of submergence}$$

S(limit) = limiting submergence value at point of change from free discharge to submerged discharge.

Values of these coefficients and exponents for several alternative structures are shown in Table C-6. When structures are located within a channel reach, the channel flow function is subdivided into upstream and downstream reaches by altering the coefficient K as follows:

$$K \text{ (upstream)} = K\left[L/L \text{ (upstream)}\right], \text{ and}$$
$$K \text{ (downstream)} = K\left[L/L \text{ (downstream)}\right]$$

where L = total length of channel reach
L (upstream) = length of upstream channel reach
L (downstream) = length of downstream channel

For structures on the Slave River the stage/discharge relationship at the Peace-Slave-Rochers confluence was modified as shown below to include the hydraulic effect of the structure:

$$H_1 = C_f \, (Q)^{N_f}$$

Coefficients and exponents for structures on the Slave River are also included in Table C-6.

Computer Model to Verify Flow Functions

A simplified computer model was developed in order to combine the individual flow functions into an overall inflow/outflow relationship from Lake Athabasca to the Peace River and thereby permit comparison with previously developed relationships. The computer model included the effects of the channel flow functions, critical depth functions and provision for the inclusion of control structures on the Slave River or Riviere des Rochers. Lake Athabasca inflows and volume changes however were not included. Thus the model represents a static condition only and for a given lake stage and Peace River discharge permits the determination of stages and flows throughout the delta network. Options with and without the Revillon Coupe

In addition to the daily data files, 5-day average data files for the above stations were developed for use in both the water balance and simulation models. A 5-day period was selected as a practical time interval for use in the simulation model, representing a compromise between the unnecessary refinement associated with a daily period and the inaccuracies inherent in a longer time period. Accordingly, each year was divided into 73 5-day time intervals commencing on January 1, with one 6-day time interval (February 25 to March 1) each leap year. Additional processed data derived from the regulated Peace River flow computations and the water balance, were added to the 5-day data file.

Daily climatological data was obtained for the Fort Chipewyan station, from the Meteorological Branch of the Ministry of Transport, Toronto in the form of punched cards and transferred to the data file.

COMPUTER PROGRAM FOR WATER BALANCE

To obtain inflow data for Lake Athabasca other than flow originating from the Peace River a water balance model for Lake Athabasca was developed based on the relationship:

Inflow = Outflow + Change in Storage Volume

The inflow to Lake Athabasca was defined as:

Inflow = Athabasca River Flow + Fond-du-Lac River Flow + Ungauged Inflow,

where ungauged inflow allows for precipitation and evaporation over the lake area. Time lags of minus one day and minus two days for Athabasca River and Fond-du-Lac River flows respectively were imposed and are reflected in the 5-day average data file values for these stations.

The outflow from Lake Athabasca was computed as:

Outflow = Slave River Flow at Fitzgerald - Peace River Flow at Peace Point.

A time lag of plus one day was imposed on Slave River flows, and again this is reflected in the 5-day average data file values for this station. This method of determining outflow unavoidably includes discharge from about 4,000 square miles of drainage area downstream of the Peace-Slave confluence which lies outside the Lake Athabasca drainage basin. Since this area represents less than 2 percent of the total drainage area no correction was applied.

This change in storage volume for Lake Athabasca was determined from recorded lake stages at Crackingstone Point and the stage-volume relationship.

Volume changes were based on smoothed lake stages determined by taking the mean of two consecutive average 5-day values as the end of time interval lake elevation. This procedure largely eliminated wind and wave effects from the recorded lake stages which often cause unrealistic variations in, and possible negative values for, the calculated lake inflows.

The water blance model was used to calculate 5-day values for the period of record from July 1, 1959 to October 31, 1971 for:

- total inflow to Lake Athabasca
- ungauged inflow to Lake Athabasca
- change in storage volume for Lake Athabasca

These data were added to the 5-day computer files.

COMPUTER MODELS FOR SIMULATION OF LAKE LEVELS

Simulation Methods

In order to determine Lake Athabasca stages and flow conditions in the various channels linking Lake Athabasca and the Peace River, both under existing conditions and with various proposed control structures, a simulation model of the system network was developed. This model involves the solution of the channel flow equations, the continuity equations at the channel confluences, and the stage/volume and water balance equations for Lake Athabasca. The elevation of Lake Athabasca at the beginning of the period analyzed is pre-specified. Peace River discharge and inflow to Lake Athabasca (as determined from the water balance model), for the 5-day time interval under consideration comprise the required input data to the system and permit the solution of the network equations.

An iterative technique (bootstrapping) was used to solve this system of equations for each specific 5-day time interval. Trial values of given variables were progressively adjusted until all constraints of the system network were satisfied for each succesive 5-day time interval. To avoid excessive oscillation during convergence and to minimize computer time, binary search techniques and step adjustments were used when required.

Due to the relatively complex nature of the network and the number of equations and variable involved, more sophisticated techniques for the solution of systems of nonlinear equations were examined. These included the Newton-Rhaphson method and the Secant method. Considerable development work on both these techniques was carried out, but in view of time and budget constraints the easier developed and controlled iterative technique was used in this study.

Extension of the existing model could include Mamawi Lake and Claire Lake, and the associated interconnecting channels. In this case the iterative technique would become unmanageable due to the system complexity, and development of one of the more sophisticated methods would be necessary.

Simulation Model

The simulation model was developed with two options, depending on the number of channels represented in the network solution: Option #1 without Revillon Coupe, and Option #2 including Revillon Coupe.

The schematic system networks for these options are illustrated in Figure C-1 and Figure C-2 respectively, and the equations involved in the solution of each are listed below

Channel Equations

Option #1	Option #2
Q12 = f(E1, E2)	Q12 = f(E1, E2)
Q13 = f(E1, E3)	Q14 = f(E1, E4)
Q23 = f(E2, E3)	Q43 = f(E4, E3)
QS = f(E3)	Q23 = f(E2, E3)
	Q42 = f(E4, E2)
	QS = f)E3)

Continuity Equations

Q23 = QP + Q12	Q23 = QP + Q12 + Q42
QS = Q13 + Q23	QS = Q23 + Q43
	Q14 = Q43 + Q42

Storage-Volume Equation

E1 = f(V)	E1 = F(V)

Water Balance Equation

Q12 + Q13 = QL + ΔV	Q12 + Q14 = QL + ΔV

The above equations provide the basis for the mathematical model of the hydraulic system. As described previously, critical depth conditions are required as a constraint on the channel flow functions and provision for this was included in the computer simulation model.

In addition to the above equations, provision for the inclusion of the hydraulic effect of control structures on the Slave River, on the Peace River and on the interconnecting channel reaches was made in the simulation model. Both free-discharge and submerged flow conditions are included and, depending on the degree of submergence, the appropriate weir flow condition is selected by the program. Simulation of the hydraulic effects of gated control structures is accomplished by closing the gates completely (zero discharge) for a set time period each year, with the gates considered fully open for the remaining time intervals. Where a control structure is stipulated the channel flow function is divided into upstream and downstream reaches and stages are calculated for each reach separately. Channel discharge is then adjusted by successive iterations, including the discharge relationship for flow over the control, until convergence is achieved.

Ice Conditions and Model Calibration

The channel flow functions described previously were developed for open water conditions only. To accomodate the effect of ice cover during the winter months provision for ice coefficients to be applied to the open water functions in the form:

$$Q(ice) = KQ(open)$$

was included in the simulation model. Theoretically, $K = 0.63$ if channel roughness is assumed constant for both open and ice conditions. However, in practice K varies from 0.2 upwards depending on conditions such as ice thickness and ice jamming. To accomodate this variation and thereby provide continuity from year to year in the simulated lake hydrographs an ice indicator with three possible options was included in the simulation model as follows:

Ice Indicator	Condition
1	Open water condition
2	Ice cover with:
	K1 for period t1
	K2 for period t2
	K3 for period t3
3	Ice jamming condition

When the ice indicator is 1 for a specific 5-day time interval, open water flow functions are used in the simulation; when the indicator is 2, the open water functions are adjusted by the appropriate K value for periods t1, t2, and t3; when the ice indicator is 3 and additional ice jamming condition is included in the simulation.

Verification of the simulated lake hydrographs was provided by comparison with recorded Lake Athabasca stages. Several computer runs were made with different K values and time periods. The best agreement between simulated and recorded lake stages was achieved with K1 = 0.6 for the period from freeze-up to December 31; K2 = 0.5 for the period from January 1 to March 16; and K3 = 0.4 for the period from March 17 to break-up.

Tests were run with ice indicator 3 for the ice jamming condition included in the simulation but the calibration was not significantly improved. Final model calibration was based on the indicator 2 condition and the effect of ice jamming is accounted for on an average basis by coefficient K3.

A comparison of the simulated and recorded lake hydrograph with no hydraulic control imposed on the hydraulic network for the 12 year period 1960-1971, is shown in Figure C-13.

It should be noted that this method of calibration for the winter ice condition imposes an average winter condition for each year of the simulation.

An improved calibration should probably be attempted, using actual winter conditions for each specific year, simulated by appropriate adjustments of K values and time periods, based on climatic parameters, such as temperature.

SUMMARY OF DISCHARGE MEASUREMENTS

RIVIERE DES ROCHERS & REVILLON COUPE

DATE	RIVIERE DES ROCHERS L.ATHABASCA TO REVILLON COUPE DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #1	Gauge WSC-3	Gauge #28	Gauge #29	RIVIERE DES ROCHERS REVILLON COUPE TO SLAVE R. DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #30	Gauge #31	Gauge #2	REVILLON COUPE DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #38	Gauge #32	Gauge #3
1971													
Jan. 5	21.7								6.63				
Feb. 17	9.01								3.94				
Mar. 16	8.7	6.47							5.10				
May 27	67.9 **	14.40		13.36	12.92				10.79c				
June 1	62.6 **	14.13		13.12	12.70	61.32*			11.07c	1.28 *	12.30		12.54
3	68.2 **	14.34		13.36	12.97		12.80	11.56	11.28c		12.62		12.69
5	76.9 *	14.76		14.00					11.14c		13.06		12.72
8	73.0 *	14.47		13.45		71.23			11.00c	1.77	12.60		12.36
9	73.6 *	14.33		13.49					11.07c		12.58		12.46
10	66.7 *	14.11		13.07		66.11			11.07c	0.59	12.41		12.52
14	73.4 *	14.64		13.98		71.93			11.42c	1.47	13.18		13.44
16	58.0 **	14.74		14.40	14.09				12.54c				
19	57.5 *	14.54		13.93					12.73c		13.79		
21	37.0 **	14.53		14.31	14.29				13.24c				
22		14.85		15.27	14.99				14.34c	-8.54 *	16.26		
23	-19.3	15.32		15.42					14.81c		16.47		
24		15.30		15.68	15.12				15.16c	-7.09			
25	25.4 *	15.42		15.22					14.81c				
28	40.0 **	14.74		14.18	14.07	46.44*			13.67c	-6.44			
30	58.3 **	14.99		14.42	14.10	59.72*			12.99c	-1.42*			14.69
July 2	48.9 **	15.16		15.05	14.58	52.18*			13.30c	-3.28*			16.14
5	35.4 **	15.48		15.37	15.02	40.15*			14.40c	-4.75*	15.64		17.12
7	49.[illegible] **	15.58		15.33	15.02	51.83*			13.80c	-2.33*	14.84		15.96
9	63.0 **	15.48		14.94	14.52	63.99*			13.18c	-0.99*	14.36		14.97
12	59.3 **	15.35		14.52	14.21	60.54*	14.07	13.27	13.05c	-1.24*			14.85
14	54.1 **	15.58		15.20	14.76	57.3 *	14.79	14.28	13.37c	-3.20*	14.76		16.14
16	29.5 **	16.23		16.22	15.96	37.63*	15.84		14.69c	-8.13	15.96		
19		16.25		16.70	15.98		16.02	15.93	16.20				
21	44.2 **	16.67		16.61	16.54	49.33*			15.80	-5.13			
26		16.92			15.51				14.04	0.923	15.28		
28	82.9 **	16.81		15.82	15.44	79.84*			13.50	3.06*	15.02		15.13
30	77.4 **	16.57		15.40	14.93	74.6 *			12.95	2.80*	14.55		14.52
Aug. 3	90.3 *	16.50		15.24					12.24		14.18		13.69
6	85.5 **	16.39		14.89	14.50	81.9 *	14.11	12.69	11.83	3.60*			13.20
9	91.5 **	16.23		14.76	14.38	87.63*	14.09	12.92	11.15	3.87*	13.47		12.48
11		16.21		14.77	14.32		13.69	12.09	10.99	3.21*	13.36		12.30
12	84.9 *	16.24		14.67					10.93		13.41		12.20
13	85.3 *	15.52		14.03					10.54		13.65		11.84
16		16.24		14.84	14.22		13.67	11.94	10.80	4.17*	13.32		12.00
17	88.8 *	15.99		14.43			13.60		10.61		13.19		11.82

TABLE C-1
Sheet 2 of 2

DATE	RIVIERE DES ROCHERS L.ATHABASCA TO REVILLON COUPE DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #1	Gauge WSC-3	Gauge #28	Gauge #29	RIVIERE DES ROCHERS REVILLON COUPE TO SLAVE R. DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #30	Gauge #31	Gauge #2	REVILLON COUPE DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #38	Gauge #32	Gauge #3
Aug. 20	90.5 **	16.17		14.60	14.38	85.79*	13.88	11.96	10.54	4.71*	13.21		11.73
23	83.7 **	15.35		13.78	12.15	80.7 *	12.69	10.99	9.92	3.00*	12.27		11.14
26	74.5 **	15.24		13.51	13.12	71.54*			9.78	2.96*	12.32	11.34	11.03
Sept. 8	76.5 **	14.42		12.66	12.52	73.99*	11.81	9.95	8.87	2.51*			10.13
17	65.6 *	13.53		11.93					8.80				10.12
28	59.2 *	12.98		11.49					8.55				9.85
Oct. 15	58.8 **	13.29		12.15	11.94	57.24*	11.62	10.34	9.81	1.56*			11.33
<u>1970</u>													
June 12	37.54*	13.83	13.83	13.28			12.98		12.45				
14	52.67*	14.33	13.82				13.46		12.48				
22	68.78*	14.70	14.06				13.32		11.44				
27				13.18						1.62*		12.41	
July 9	58.86*	14.32	13.56				12.88e		10.93c				
10		14.85		12.55					11.34c	2.10		12.79	13.06
14	62.91**	14.60			12.94	60.88*	12.81		10.93c	2.03*		12.00	
16	68.0 **	14.85			13.14	65.14*	12.90e		10.72c	2.86*		11.98	
18	69.53**	14.95			13.16	66.72*	12.83e		10.79c	2.81*		11.69	
20	71.33**	14.45			12.74	68.3 *	12.55e		10.22c	3.03*		11.28	
23	69.49**	14.25			12.14	67.32*	11.83e		9.49c	2.17*		11.03	
27	73.22**	14.53			12.73	70.32*	12.50e		9.64c	2.90*		10.97	
Aug. 24	65.81**	13.34			11.67	64.1 *	11.26e		8.49c	1.71*		9.67	9.10
Oct. 31					9.69				7.18c	1.13*		8.12	
<u>1960</u>													
June 10	36.[illegible]9*	16.98	16.81				16.60e		16.20				
July 1	-37.88	19.34	19.50				19.54	19.52	19.69				
Aug. 10	114.7 *	20.11	19.14				17.96	16.84	15.77				
Sept. 7	104.1 *	18.81	17.86				16.68	15.44	14.35				
Oct. 11	109.2 *	18.34	17.14			102.77	15.59	13.86	12.63	6.43			

"c" indicates value computed

"e" indicates value estimated

"*" indicates discharge value together with associated stage values comprising a data set, included in the regression analysis

"**" indicates data sets included in the regression analysis for the Riviere des Rochers from Lake Athabasca to the Revillon Coupe confluence, as well as in the regression analysis for the Riviere des Rochers from Lake Athabasca to the Slave River

NOTE:- Guage numbers refer to Alberta Water Resources' designations

TABLE C-2

SUMMARY OF DISCHARGE MEASUREMENTS

CHENAL DES QUATRE FOURCHES

DATE		DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #1	Gauge #33	Gauge #34	Gauge #35	Gauge #3
1971							
Jan.	5	0.187					
March	15	0.0					
May	13	3.87					
	28	5.40	14.28				
June	2	4.67 *	14.22	14.00		12.38	12.60
	3	5.03 *	14.34	14.10		12.61	12.69
	6	5.97 *	14.42	14.12		12.50	12.52
	8	5.95 *	14.47	14.18		12.28	12.36
	10	4.82 *	14.11	13.87		12.37	12.52
	14	5.11 *	14.64	14.63		12.91	13.44
	16	- 4.87	14.74	14.96		14.29	
	18	- 4.22	14.64	14.74		14.95	
	21	- 9.8	14.53	14.82			
	23	-16.0	15.32			18.21	
	25	- 7.7	15.42	14.94		17.02	
	28	- 6.38	14.74			15.17	
	30	- 2.74	14.99	14.96		14.52	14.69
July	2	- 8.24 *	15.16			15.58	16.14
	5	- 9.58 *	15.48			16.81	17.12
	12	- 2.02	15.35			14.52	14.85
	14	- 6.63 *	15.58		16.23	15.70	16.14
	16	-13.1	16.10		18.45		
	19	-14.2	16.25	16.73	18.63	18.92	
	21	-10.6	16.67	16.85		18.06	
	26	2.88	16.92	16.53			
	27	5.78	16.81	16.48	16.46		
	30	6.02 *	16.57	16.27			14.52
Aug.	5	9.27 *	16.80	16.26		13.88	13.39
	11	8.03 *	16.21	15.82	14.96		12.30
	16	9.25 *	16.24	15.68			12.00
	18	8.7 *	15.98	15.49			11.72
	20	9.17 *	16.17	15.51			11.73
	23	7.87 *	15.35				11.14
Sept.	3	7.37 *	15.49	15.11			11.43
	9	7.19 *	14.54	14.13	13.22	10.93	10.17

DATE		DISCHARGE 1000 CFS	W.S. EL. LESS 670.0 Ft. Gauge #1	Gauge #33	Gauge #34	Gauge #35	Gauge #3
Sept.	16	7.79 *	14.46	14.08			10.43
	21	7.21 *	13.96		12.87		10.39
	24	7.65 *	14.15				11.06
	27	5.78 *	13.73				10.33
	29	5.67 *	13.36	12.82			9.78
Oct.	12	4.82 *	12.63	12.06			10.59
	18	3.36 *	12.78	11.91			10.54
1970							
June	16	1.69 *	14.17	14.50			13.77
	17	2.4 *	14.40	14.33			13.77
	19	2.26 *	14.00	13.70			13.06
	23	5.68 *	15.10	14.50			12.97
July	2	5.1 *	10.27	13.96			12.39
	10	5.11 *	14.85	14.41			13.06
	16	6.59 *	14.85	14.71			11.98 @
	18	7.37 *	14.95	14.49			11.69 @
	21	7.2	15.00	14.22e			
	23	6.94 *	14.25	13.69			11.03 @
	26	7.16 *	14.80	14.19			10.57
	27	7.11 *	14.53	14.15			10.97 @
	28	7.24	14.54	13.97			
Aug.	6	5.62 *	14.15	13.78	13.34		11.20
	24	6.64 *	13.34	12.83	12.14		9.10
1960							
May	27	-14.22 *	15.06	15.92			19.56
June	10	-11.76 *	16.98	16.95			19.60
July	1	-22.56 *	19.34	19.75			24.26
Aug.	10	10.29 *	20.11	19.69			17.50
Sept.	7	10.88 *	18.81	18.70			15.93
Oct.	12	11.65 *	18.24	18.31			14.05

"*" indicates discharge value together with associated stage values comprising a data set, included in the regression analysis

"@" indicates gauge #32 value in place of gauge #3 value

NOTE:- Guage numbers refer to Alberta Water Resources' designations

TABLE C-3

SUMMARY OF DISCHARGE MEASUREMENTS

PEACE RIVER FROM QUATRE FOURCHES TO ROCHERS CONFLUENCE

DATE		W.S. ELEV. LESS 670.0 Ft. Gauge #3	Gauge #2	DISCHARGE - 1000 CFS 1 SLAVE R. @ FITZGERALD	2 RIVIERE DES ROCHERS	3 REVILLON COUPE	4 PEACE RIVER @ PEACE POINT	5 CHENAL DES QUATRE FOURCHES	PEACE RIVER REACH 1 - 2 + 3	3 + 4 + 5
1971										
June	1	12.54	11.07 c	152.0	62.6	1.3	74.0		90.7 *	
	2	12.60	11.14 c	153.0		1.4e	74.8	4.7		80.9 *
	3	12.69	11.28 c	155.0	68.2	1.5e	73.9	5.0	88.3 *	80.4 *
	5	12.72	11.14 c	153.0	76.9	2.0e	68.3		82.1 *	
	6	12.52	11.42 c	157.0		2.1e	66.5	6.0		74.6*
	8	12.36	11.00 c	151.0	73.0	1.8	67.3	6.0	80.8 *	75.1 *
	9	12.46	11.07 c	152.0	73.6	1.7e	70.8		80.1 *	
	10	12.52	11.07 c	152.0	66.7	0.6	73.9	4.8	85.9 *	79.3 *
	14	13.44	11.42 c	157.0	73.4	1.5	91.7	5.1	92.1 *	98.3 *
	30	14.69	12.99 c	181.0	58.3	-1.4	113.0	-2.7	119.3 *	108.9 *
July	2	16.14	13.30 c	186.0	48.9	-3.3	169.0	-8.2	145.8 *	157.5 *
	5	17.12	14.40 c	104.0	35.4	-4.8	163.0	-9.6	160.8 *	148.6 *
	7	15.96	13.80 c	194.0	49.5	-2.3	128.0		138.2 *	
	9	14.97	13.18 c	184.0	63.0	-1.0	105.0		118.0 *	
	12	14.85	13.05 c	182.0	59.3	-1.2	115.0	-2.0	120.5 *	111.8 *
	14	16.14	13.37 c	187.0	54.1	-3.2	151.0	-6.6	140.7 *	141.2 *
	28	15.13	13.50	191.0	82.9	3.1	86.0		107.2 *	
	30	14.52	12.95	181.0	77.4	2.8	77.6	6.0	106.4 *	86.4 *
Aug.	3	13.69	12.24	174.0	90.3	3.8	65.8		82.5 *	
	5	13.39	12.04	168.0		3.7	60.9	9.3		73.9 *
	6	13.20	11.83	168.0	85.5	3.6	58.6		81.1 *	
	9	12.48	11.15	156.0	91.5	3.9	51.6		67.4 *	
	11	12.30	10.99	151.0		3.2	49.4	8.0		60.6 *
	12	12.20	10.93	151.0	84.9	3.4	48.6		68.5 *	
	13	11.84	10.54	150.0	85.3	3.5	48.5		63.2 *	
	16	12.00	10.80	151.0		4.2	45.0	9.3		58.5 *
	17	11.82	10.61	147.0	88.8	4.5	44.7		60.7 *	
	18	11.72	10.51	145.0		4.6	44.8	8.7		58.1 *
	20	11.73	10.54	145.0	90.5	4.7	45.0	9.2	60.2 *	58.9 *
	23	11.14	9.92	141.0	83.7	3.0	42.6	7.9	56.3 *	53.5 *
	26	11.03	9.78	136.0	74.5	3.0	44.4		63.5 *	
Sept.	3	11.43	10.25	140.0		2.7	42.3	7.4		52.4 *
	8	10.13	8.87	126.0	76.5	2.5	39.1		51.0 *	
	9	10.17	8.91	125.0		2.5	40.0	7.2		49.7 *
	16	10.40	9.14	124.0		2.0	43.3	7.8		53.1 *
	17	10.12	8.80	124.0	65.6	2.0	45.0		56.4 *	
	21	10.39	9.11	124.0		1.9	47.3	7.2		56.4 *
	24	11.06	9.83	130.0		1.9	48.1	7.7		57.7 *
	27	10.33	9.10	126.0		1.8	45.1	5.8		52.7 *
	28	9.85	8.55	119.0	59.2	1.8	45.8		57.6 *	
	29	9.78	8.46	115.0		1.8	46.5	5.7		54.0 *
Oct.	12	10.59	8.95	124.0		1.6	66.8	4.8		73.2 *
	15	11.33	9.81	133.0	58.8	1.6	67.8		72.8 *	
	18	10.54	9.02	124.0		1.5	58.0	3.4		62.9 *

"c" indicates value computed

"e" indicates value estimated

"*" indicates discharge value together with associated stage values comprising a data set, included in the regression analysis

NOTE:- Guage numbers refer to Alberta Water Resources' designations

TABLE C-4
Sheet 1 of 2

SUMMARY OF STAGE-DISCHARGE DATA

PEACE RIVER, SLAVE RIVER, RIVIERE DES ROCHERS CONFLUENCE

DATE	W.S. ELEV. LESS 670.0 Ft.	DISCHARGE 1000 CFS
1971		
May 6	12.28	176.0
29	10.81	148.0
July 17	16.14	226.0
18	16.31	230.0
19	16.20	229.0
20	16.10	226.0
21	15.80	222.0
22	15.47	212.0
23	15.48	216.0
24	14.74	210.0
25	14.24	206.0
26	14.04	196.0
27	13.89	196.0
28	13.50	191.0
29	13.19	187.0
30	12.95	181.0
31	12.78	181.0
Aug. 1	12.72	179.0
2	12.50	178.0
3	12.24	174.0
4	12.06	169.0
5	12.04	168.0
6	11.83	168.0
7	11.72	163.0
8	11.46	161.0
9	11.15	156.0
10	11.07	155.0
11	10.99	151.0
12	10.93	151.0
13	10.54	150.0
14	10.64	145.0
15	11.07	148.0
16	10.80	151.0
17	10.61	147.0
18	10.51	145.0
19	10.47	144.0
29	10.54	145.0
21	10.58	146.0
22	10.31	144.0
23	9.92	141.0
24	9.84	137.0
25	9.87	136.0
26	9.78	136.0
27	9.91	135.0
28	10.03	137.0
29	9.92	137.0
30	9.87	136.0
31	9.92	135.0
Sept. 1	10.04	136.0
2	10.52	140.0
3	10.25	144.0
4	9.63	138.0
5	9.49	132.0
6	9.21	130.0
7	8.99	127.0
8	8.87	126.0
9	8.91	125.0
10	9.00	124.0
11	9.18	123.0
12	8.81	122.0
1971		
13	8.48	121.0
14	8.38	115.0
15	9.03	119.0
16	9.14	124.0
17	8.80	124.0
18	8.92	120.0
19	9.01	121.0
20	9.19	123.0
21	9.11	124.0
22	9.26	124.0
23	9.43	126.0
24	9.83	130.0
25	10.13	134.0
26	9.78	135.0
27	9.10	126.0
28	8.55	119.0
29	8.46	115.0
30	8.59	117.0
Oct. 1	8.66	118.0
2	8.68	118.0
3	8.78	120.0
4	8.96	122.0
5	9.02	123.0
6	9.18	125.0
13	9.71	124.0
14	9.87	131.0
15	9.81	133.0
16	9.48	130.0
17	9.23	126.0
18	9.02	124.0
19	8.82	121.0
20	8.76	120.0
21	8.60	119.0
22	8.51	117.0
23	8.38	116.0
24	8.39	116.0
Oct. 25	7.89	114.0
26	7.87	106.0
27	8.46	111.0
1960		
April 14	10.76	142.0
15	10.93	148.0
16	11.28	150.0
17	11.70	155.0
18	11.93	159.0
19	12.43	164.0
20	12.85	171.0
21	13.31	177.0
22	13.73	183.0
23	13.55	185.0
24	13.70	184.0
25	14.29	190.0
26	14.98	196.0
27	15.49	206.0
28	15.41	210.0
29	15.33	213.0
30	16.02	217.0
31	15.94	218.0

TABLE C-4
Sheet 2 of 2

DATE		W.S. ELEV. LESS 670.0 Ft.	DISCHARGE 1000 CFS
1960			
June	1	16.11	220.0
	2	16.15	223.0
	3	16.45	227.0
	4	16.56	230.0
	5	16.27	228.0
	6	16.35	227.0
	7	16.63	227.0
	8	15.67	222.0
	9	16.06	221.0
	10	16.20	223.0
	11	16.03	221.0
	12	15.90	220.0
	13	16.21	220.0
	14	16.53	228.0
	15	16.59	233.0
	16	16.82	235.0
	17	16.89	236.0
	18	16.96	235.0
	19	16.99	238.0
	20	17.16	239.0
	21	17.24	240.0
	22	17.16	241.0
	23	17.36	242.0
	24	17.48	245.0
	25	17.84	248.0
	26	18.73	262.0
June	27	19.01	272.0
	28	19.74	280.0
	29	19.33	280.0
	30	19.32	279.0
July	1	19.69	282.0
	2	19.61	283.0
	3	19.57	282.0
	4	19.67	283.0
	5	19.62	283.0
	6	19.64	282.0
	7	19.94	284.0
	8	19.48	286.0
	9	18.57	271.0
	10	19.31	270.0
	11	19.48	271.0
	12	19.41	270.0
	13	19.24	268.0
	14	19.35	268.0
	15	19.13	268.0
	16	18.86	263.0
	17	18.54	259.0
	18	18.19	254.0
	19	18.12	249.0
	20	17.93	247.0
	21	17.85	244.0
	22	17.90	244.0
	23	17.96	245.0
	24	18.04	243.0
	25	17.44	241.0
	26	17.68	240.0
	27	17.57	238.0
	28	17.26	235.0
	29	17.07	232.0
	30	16.86	229.0
	31	16.80	229.0

DATE		W.S. ELEV. LESS 670.0 Ft.	DISCHARGE 1000 CFS
1960			
Aug.	1	16.61	228.0
	2	16.60	225.0
	3	16.41	222.0
	4	16.33	221.0
	5	16.23	220.0
	6	16.13	218.0
	7	15.93	216.0
	8	15.92	214.0
	9	15.86	213.0
	10	15.77	213.0
	11	15.68	212.0
	12	15.36	207.0
	13	15.30	206.0
	14	15.08	203.0
	15	14.85	200.0
	16	14.49	196.0
	17	14.33	192.0
Aug.	18	14.24	189.0
	19	14.25	188.0
	20	14.22	189.0
	21	14.21	188.0
	22	14.56	192.0
	23	14.72	195.0
	25	14.54	191.0
	26	14.70	192.0
	27	14.77	193.0
	28	14.54	193.0
	29	14.60	192.0
	30	14.55	192.0
	31	14.52	192.0
Sept.	1	14.55	193.0
	2	13.89	187.0
	3	14.10	185.0
	4	14.10	185.0
	5	14.43	186.0
	7	14.35	192.0
	8	14.13	187.0
	9	14.30	186.0
	10	14.45	189.0
	11	14.47	191.0
	12	14.83	194.0
	13	15.05	198.0
	14	15.18	202.0
	15	14.41	198.0
	16	14.22	188.0
	17	14.51	189.0
	18	14.22	189.0
	19	13.96	184.0
	20	13.98	184.0
	22	13.58	178.0
	24	13.38	176.0
	25	13.44	174.0
	26	13.20	173.0
	27	13.17	172.0
	28	13.05	170.0
	29	13.01	170.0
Oct.	7	13.15	171.0
	11	12.63	161.0
	12	12.84	165.0

TABLE C-5

CHANNEL FLOW FUNCTIONS

CHANNEL	K	x	E(Base)	Cc	Kc	y	Manning's "n" @ W. S. elev.			
							675.0	680.0	685.0	690.0
RIVIERE DES ROCHERS										
- L. Athabasca to Slave R.	0.3577	1.47	660.0	0.491	1.25	0.504	0.031	0.027	0.025	0.025
- L. Athabasca to Revillon Coupe	0.0217	2.67	665.0	0.679	2.96	0.326	0.064	0.032	0.021	0.016
- Revillon Coupe to Slave R.	0.7400	1.33	660.0	0.450	0.656	0.583	0.034	0.030	0.027	0.026
REVILLON COUPE	0.00158	2.525	665.0	0.669	7.66	0.337	0.029	0.025	0.022	0.022
CHENAL DES QUATRE FOURCHES	0.001753	2.646	665.0	0.685	7.30	0.308	0.028	0.022	0.020	0.019
PEACE RIVER										
- Quatre Fourches to Rochers	0.0201	2.613	660.0	0.674	3.45	0.310	0.054	0.035	0.026	0.021
SLAVE RIVER	1.696	0.5043	660.0							

TABLE C-6

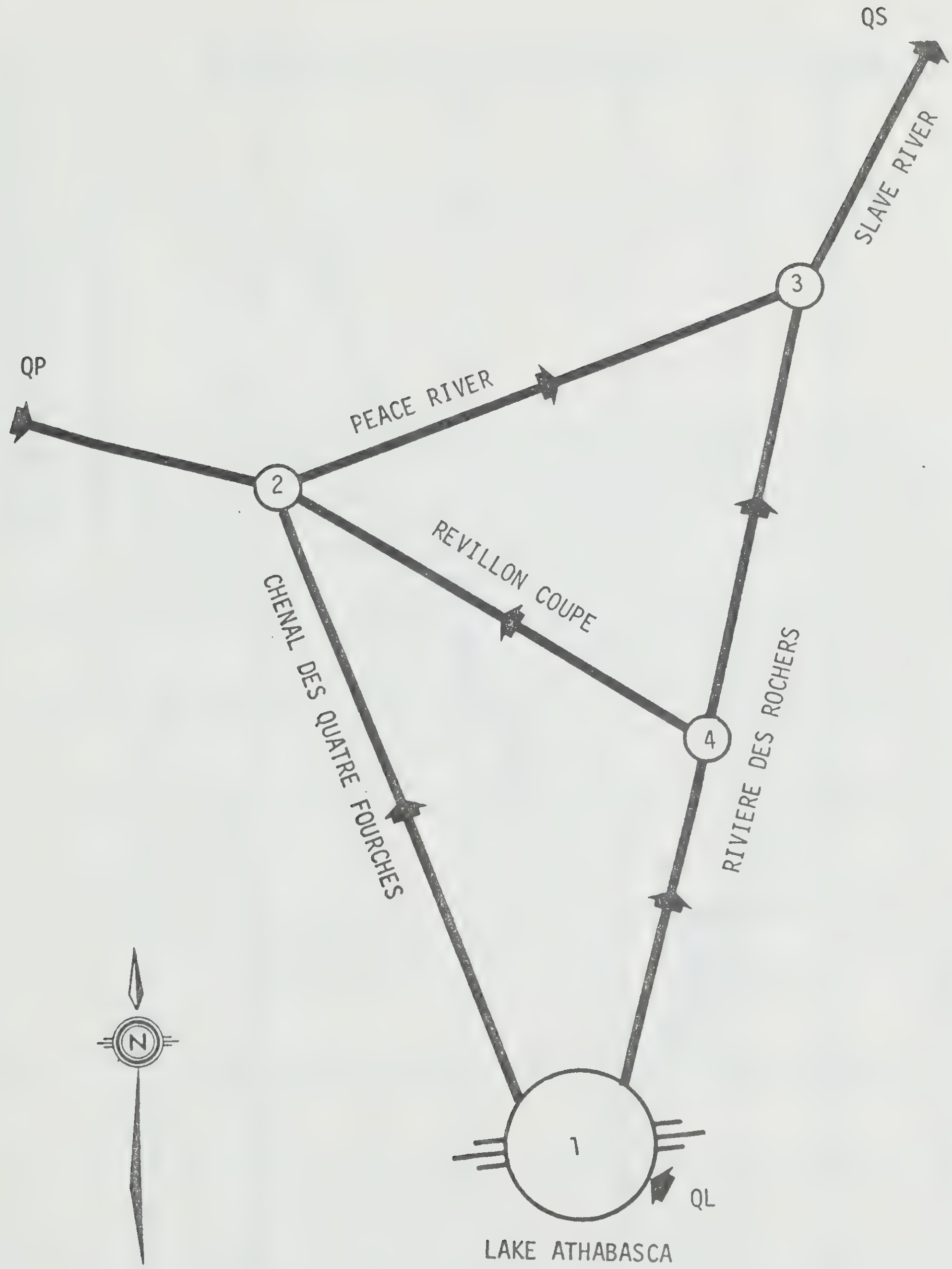
CONTROL STRUCTURE FLOW FUNCTIONS

STRUCTURE	Cf	Cs	W	H(crest)	Nf	Ns	S(limit)	L (miles)	L(U/S)	L(d/s)
SLAVE RIVER SITE 1										
A/ Rockfill Construction(75%)	1.17	-	-	-	0.598	-	-	-	-	-
B/ Gated Concrete Control Structure (10-50 ft gates)	2.67	-	-	-	0.472	-	-	-	-	-
RIVIERE DES ROCHERS SITE 2										
A/ Rockfill Notch Weir (V)	0.0118	0.006	1.0	0	2.60	-2.06	0.76	17.3	6.4	10.9
B/ Rockfill Weir	0.00229	.00235	700	17.0	1.60	-1.09	0.80	17.3	6.4	10.9
C/ Gated Concrete Control Structure (6-40 ft. gates)	0.0038	0.00275	230	10.0	1.50	-1.13	0.61	17.3	6.4	10.9

PEACE-ATHABASCA DELTA CHANNEL NETWORK

OPTION # 1

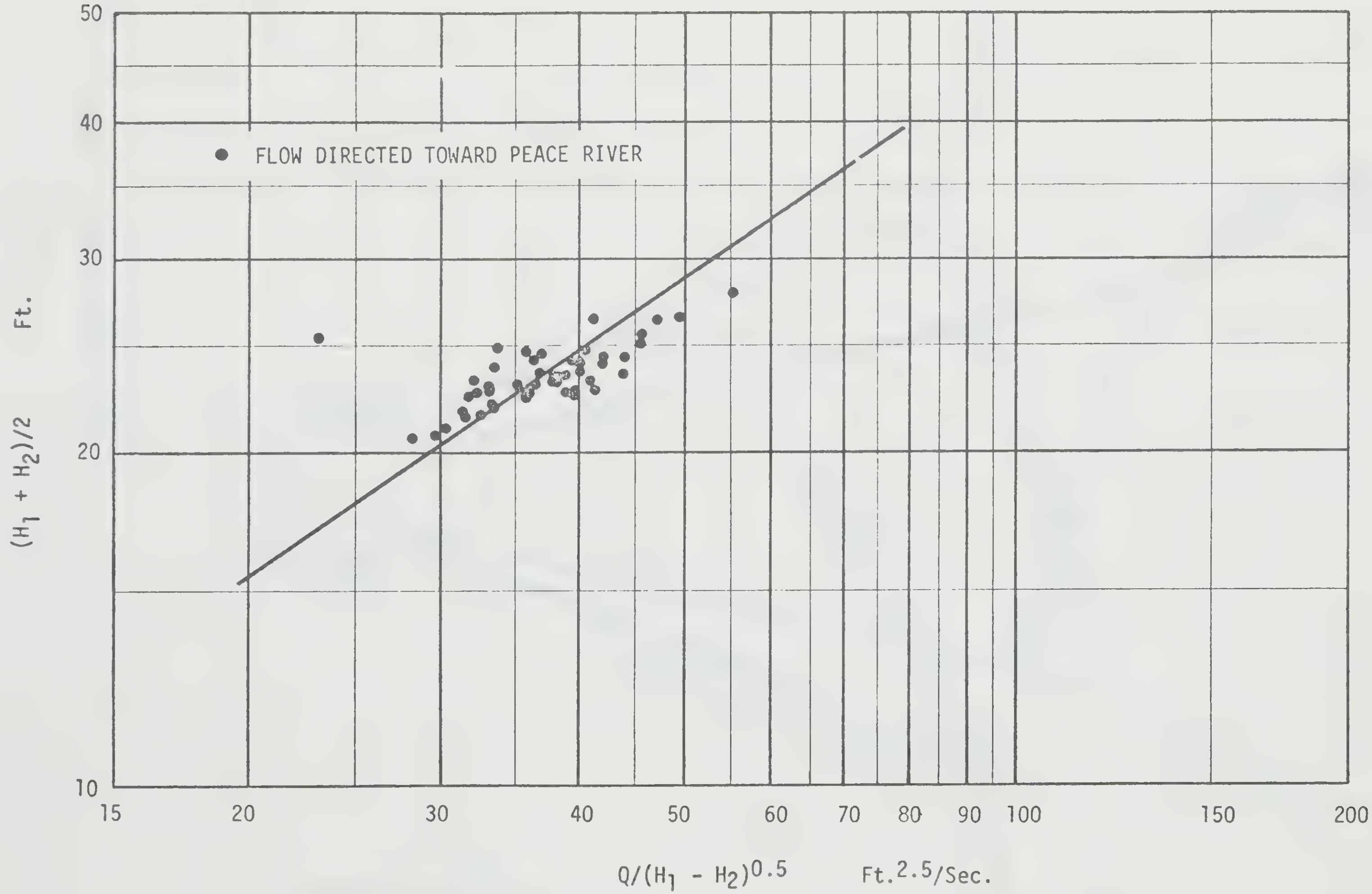
FIG. C-1



PEACE-ATHABASCA DELTA CHANNEL NETWORK

OPTION # 2

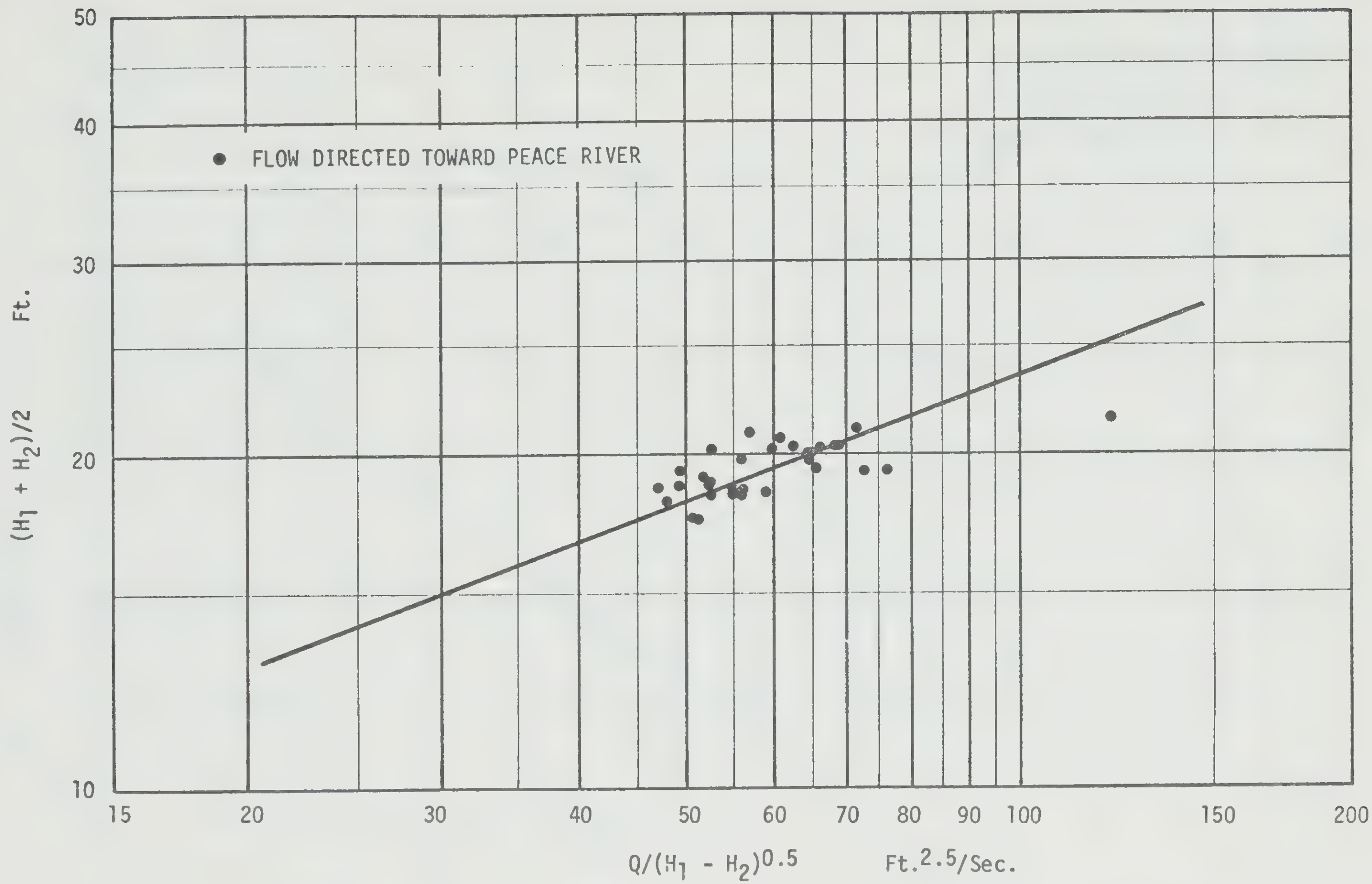
FIG. C-2



CHANNEL FLOW FUNCTIONS

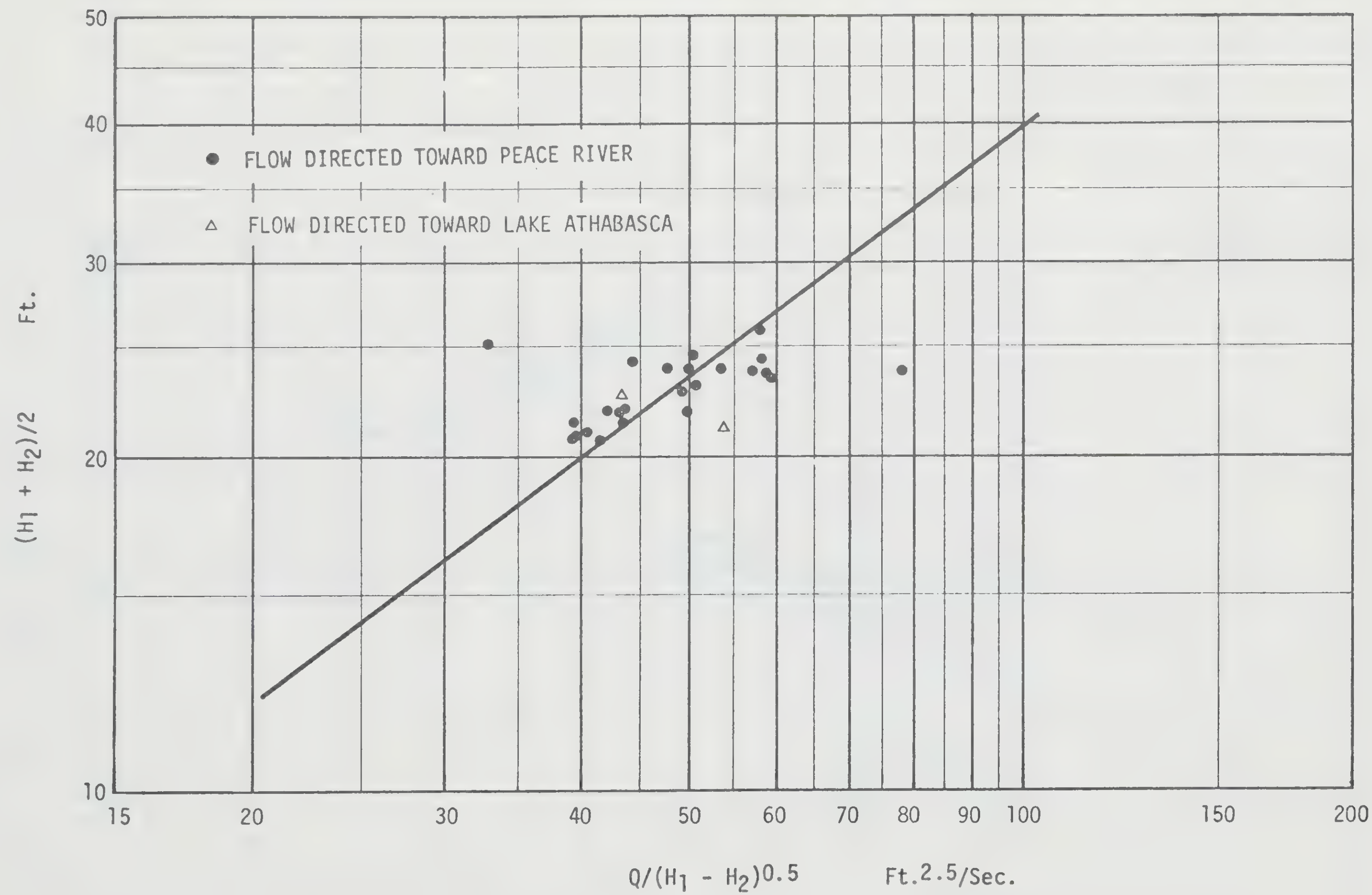
RIVIERE DES ROCHERS
(Lake Athabasca to Slave River)

FIG. C-3



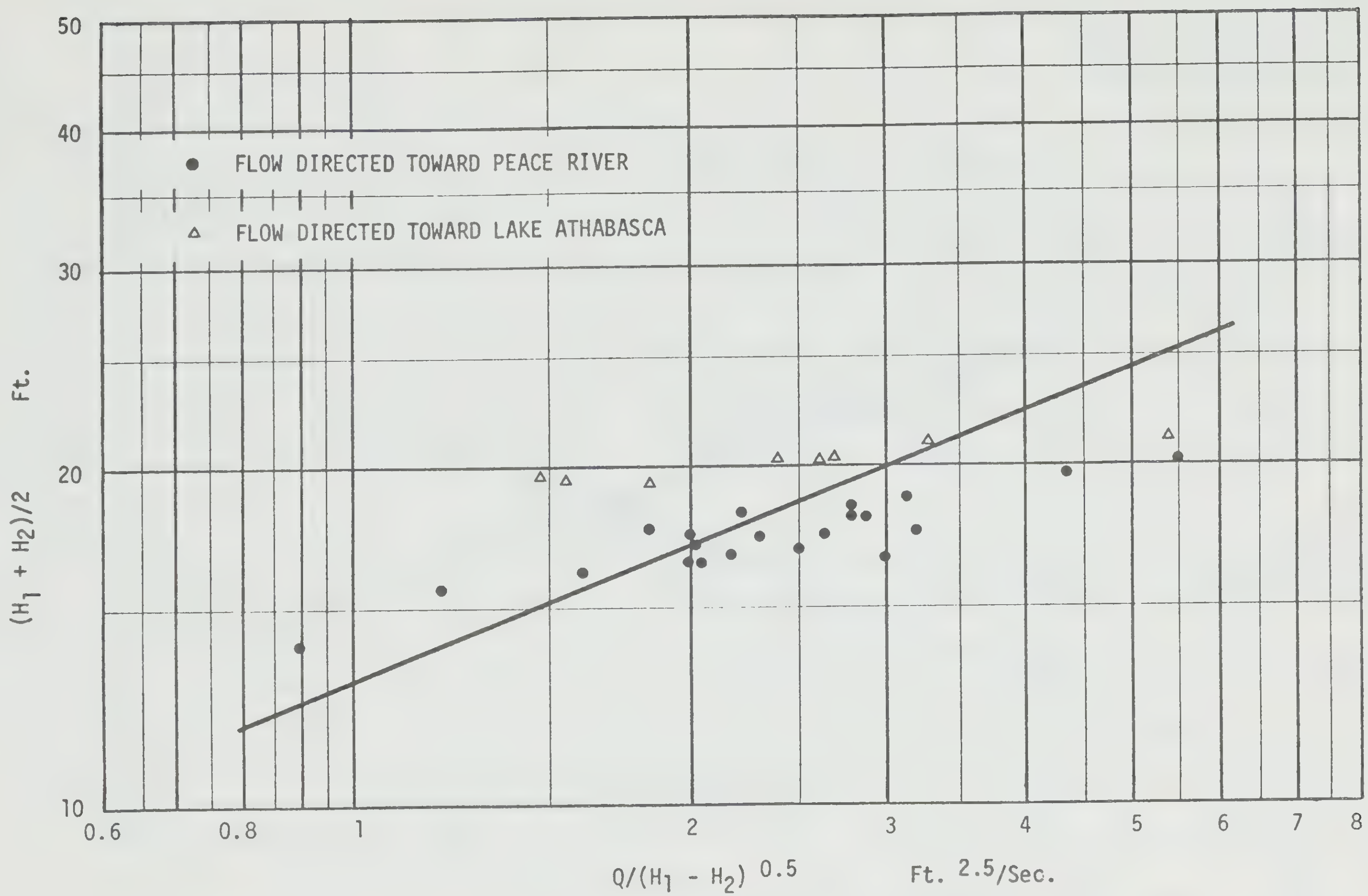
CHANNEL FLOW FUNCTIONS
RIVIERE DES ROCHERS
(Lake Athabasca to Revillon Coupe)

FIG. C-4



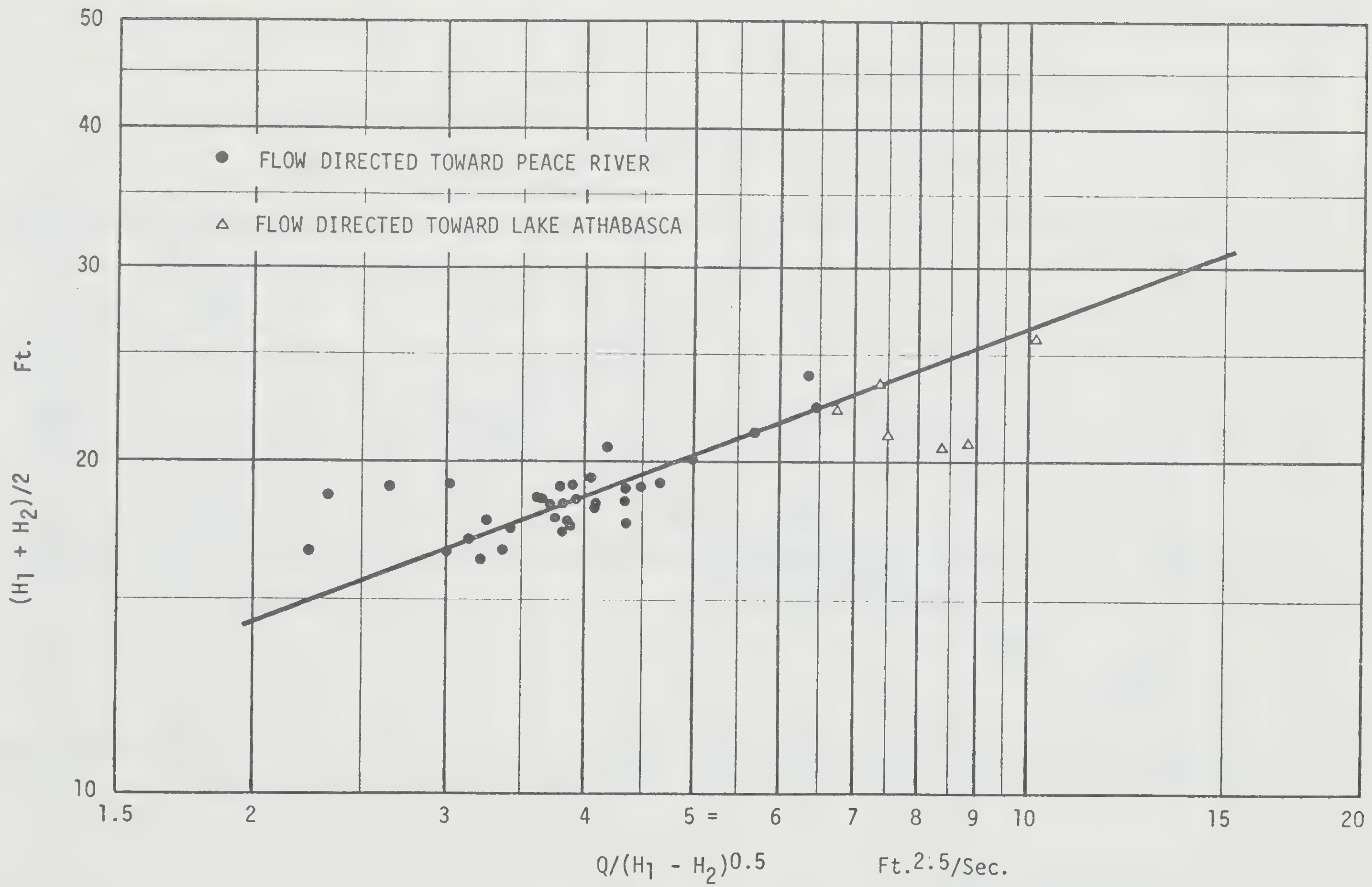
CHANNEL FLOW FUNCTIONS
RIVIERE DES ROCHERS
(Revillon Coupe to Slave River)

FIG. C-5



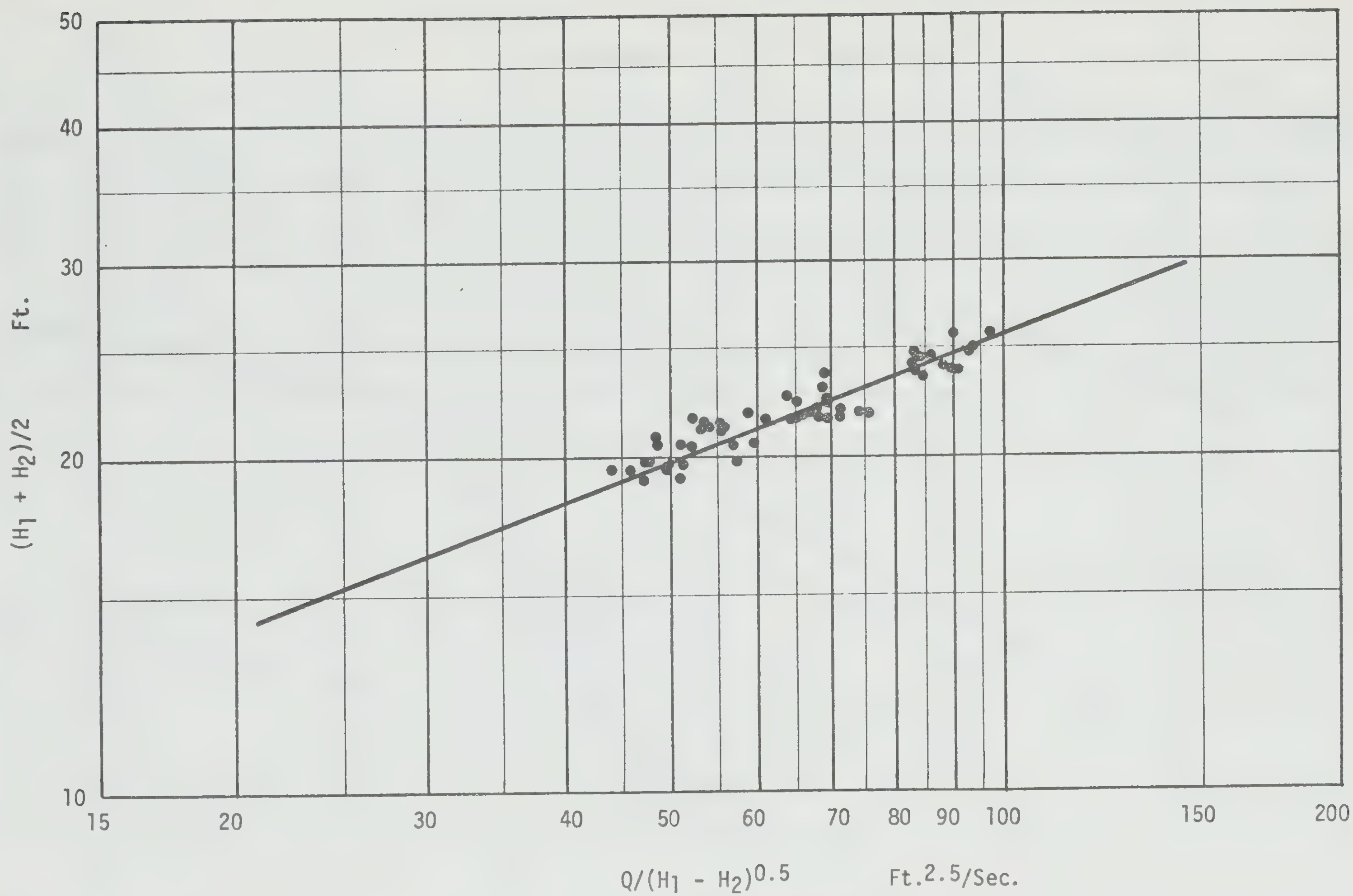
CHANNEL FLOW FUNCTIONS
REVILLON COUPE
(Riviere des Rochers to Peace River)

FIG. C-6



CHANNEL FLOW FUNCTIONS
CHENAL DES QUATRE FOURCHES
(Lake Athabasca to Peace River)

FIG. C-7



CHANNEL FLOW FUNCTIONS
PEACE RIVER
(Chenal des Quatre Fourches to Riviere des Rochers)

FIG. C-8

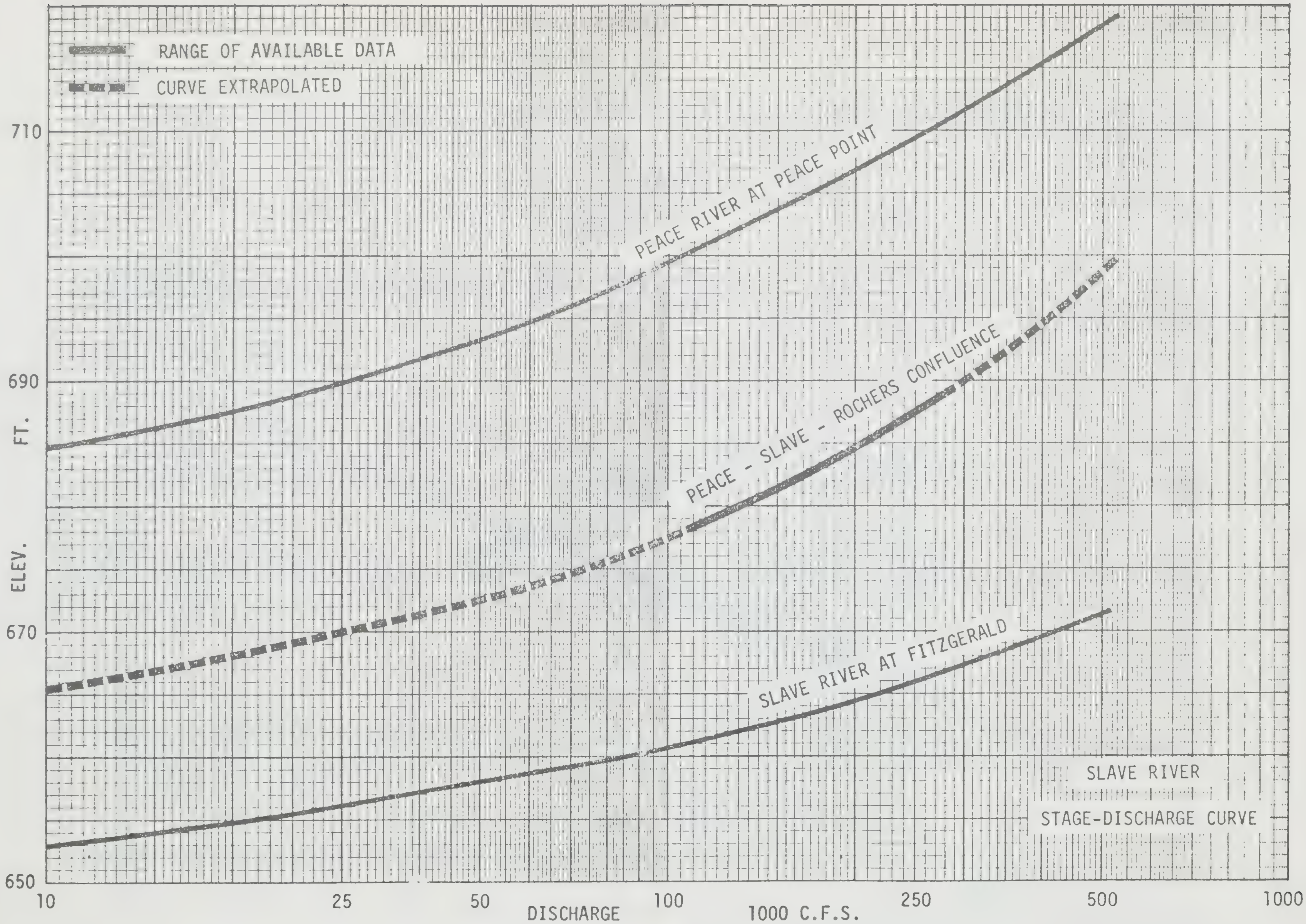

RANGE OF AVAILABLE DATA
CURVE EXTRAPOLATED
PEACE RIVER AT PEACE POINT
PEACE - SLAVE - ROCHERS CONFLUENCE
SLAVE RIVER AT FITZGERALD
SLAVE RIVER
STAGE-DISCHARGE CURVE
710
690
670
650
ELEV. FT.
10
25
50
100
250
500
1000
DISCHARGE 1000 C.F.S.

FIG. C-9

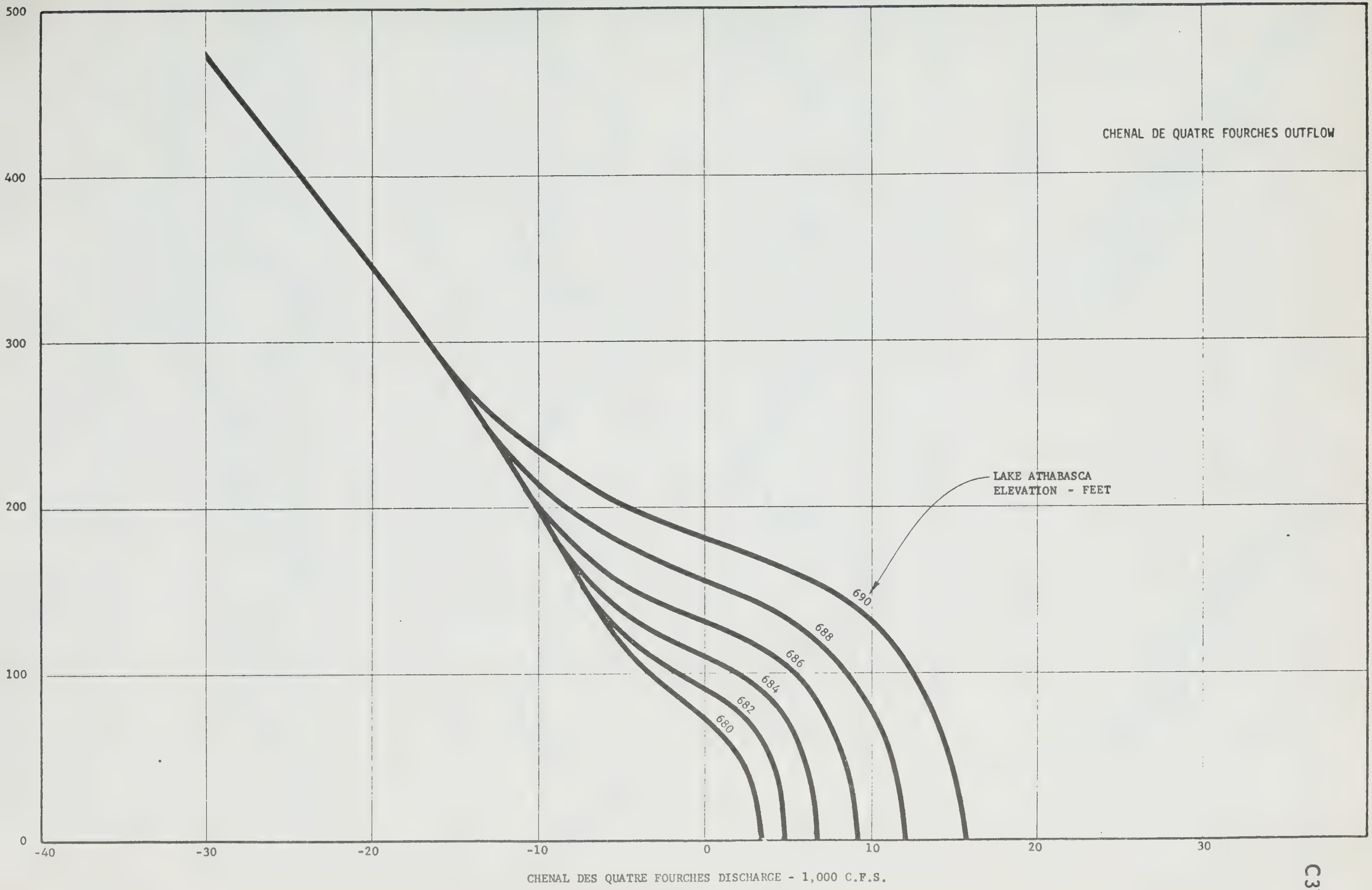
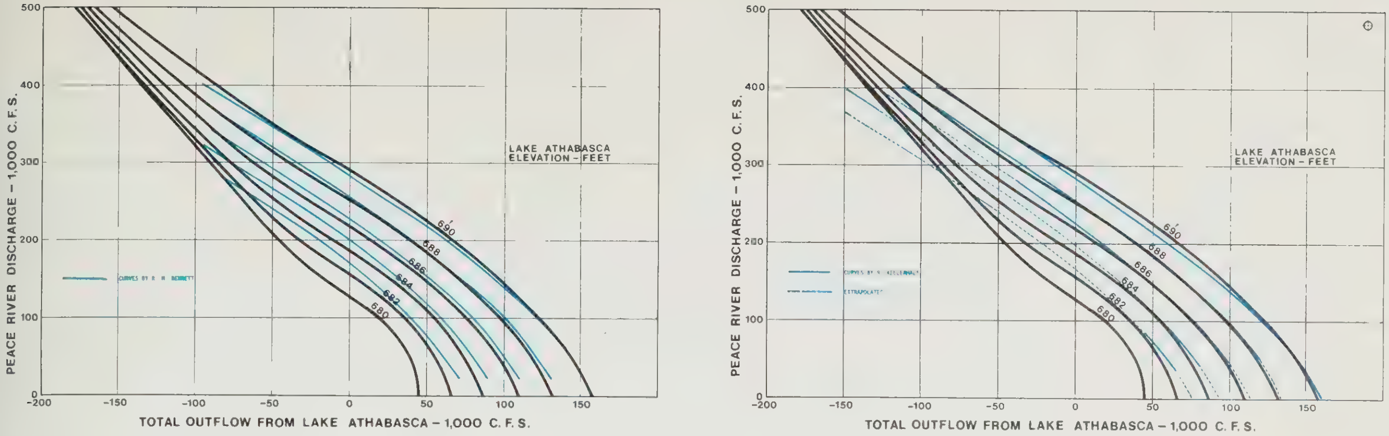

CHENAL DE QUATRE FOURCHES OUTFLOW
LAKE ATHABASCA
ELEVATION - FEET
690
688
686
684
682
680
500
400
300
200
100
0
-40
-30
-20
-10
0
10
20
30
CHENAL DES QUATRE FOURCHES DISCHARGE - 1,000 C.F.S.

FIG. C-12



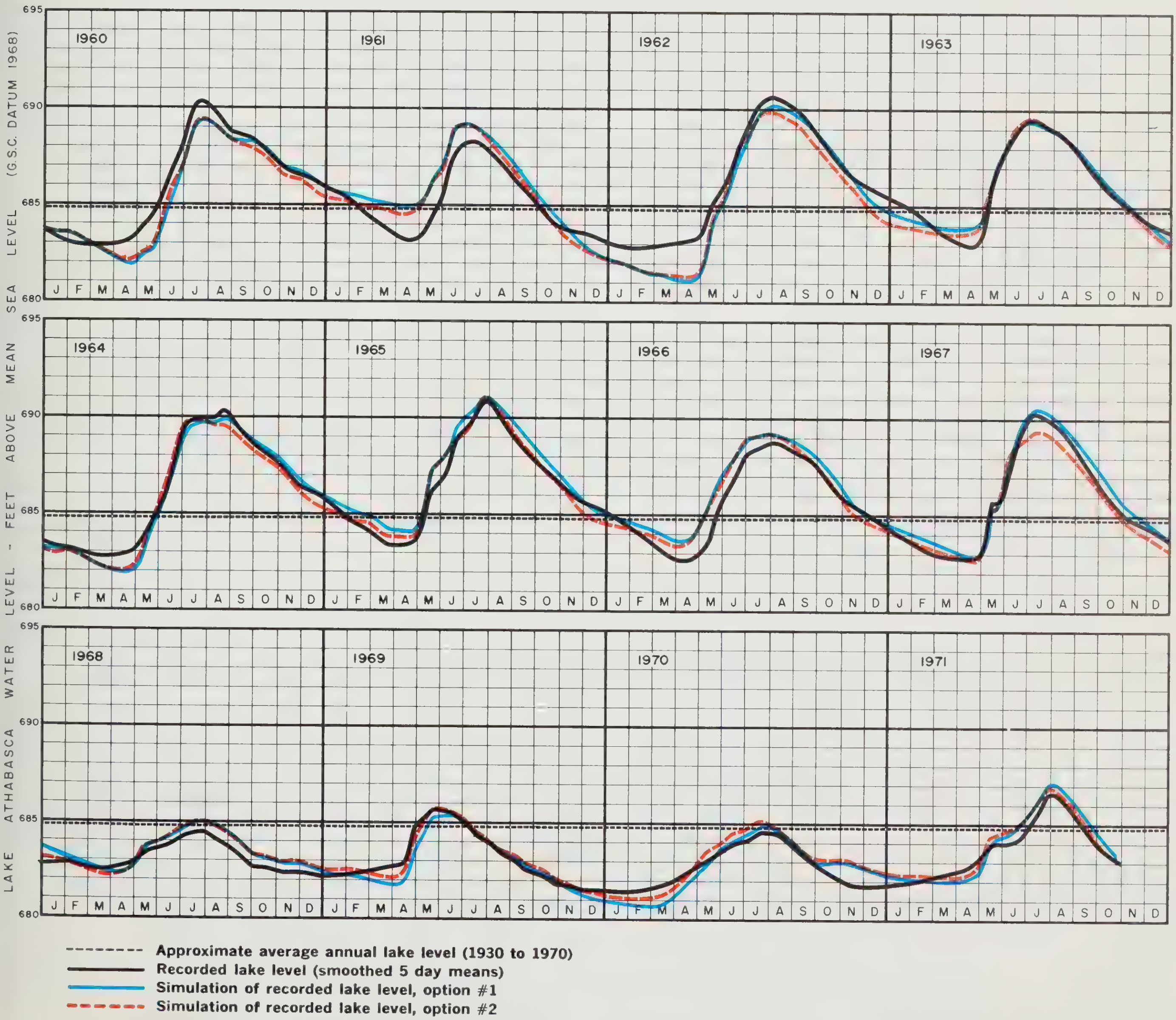


FIGURE C-13 Lake Athabasca Hydrographs, illustrating calibration of the Simulation Model, using Option 1 and 2

S E C T I O N   C

A P P E N D I X   C - 1

LAKE ATHABASCA

SIMULATION ALGORITHM

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Alberta Department of the Environment
Water Resources Division

December, 1971

LAKE ATHABASCA

SIMULATION ALGORITHM

The algorithms used to obtain results contained in the report "Athabasca Delta Project Report #1 (Peace Athabasca Delta Symposium 1971)" have never been published in detail. This report is in response to inquiries that have been received by the author and is intended to point out the advantages and the flexibility of the method. A working knowledge of the above is assumed.

GENERAL APPROACH - WATER LEVELS

Others (e.g. Kellerhals, Bennett, Coulson) have simulated natural conditions on Lake Athabasca with fair to good success. All or most of these methods do not use water levels throughout as the basis of the system's simulation. Therefore, these models have several disadvantages:

i. the effects of all types of structures at all locations cannot be studied.

ii. the effects of ice jamming on the Slave River cannot be determined

iii. winter ice conditions are more difficult to simulate

iv. channel regime characteristics and changes in time cannot be studied and the effects predicted.

v. outflow is not determined for individual outflow channels

vi. outflow relationships used in some cases were such that outflow was not always zero when water levels at both channel ends were equal.

The algorithm used in the Water Resources Model (WR Model) does not have these disadvantages because water levels have been used throughout. In addition, is should be noted that the additional sophistication of treating the system as a series of 2 or more lakes could be added to the WR Model easily (if justified by the availability of separate inflow data).

OTHER USAGE OF THE BASIC ALGORITHM

The author has previously sucessfully used this algorithm with adaptations to:

i. Pembina River at Entwistle Reservoir Routing, 1968 (controlled low level outlet, main spillway, auxiliary spillway, diversion tunnel, secondary storage reservoir, fixed operating levels, flood warning period, multiple hydrographs)

ii. Water - A Generalized Flood Routing and Reservoir Program for Timesharing, May 1970
This program, developed on CGE Mark II timesharing system, is an easy to use spillway design program incorporating all the elements of item i above with the facility to selectively change design parameters. This program has been used by Alberta Water Resources personnel on roughly 50 projects of varying complexity and size.

iii. Gull Lake Report, August 1971
The most complex adaptation to date (which required the addition of a binary search) occurred with the Gull Lake Pumping Design. This involved (a) a case of uncontrolled low level reservoir outlet, uncontrolled spillway, 3 stepped electric diversion pumps, cut in-cut out at different levels and minimum pumping level; (b) a case like (a) except 2 variable rate gas pumps each with one fixed elevation at which the pump cuts in and out. A pump speed up factor was also employed above a fixed elevation common to both pumps.

BASIC ALGORITHM

A/ Symbols

Flow (c.f.s.)

Q_R outflow of Rochers channel

Q_F outflow of Quatre Fourches channel

I Lake Athabasca Inflow

Q_S flow in Slave River at confluence of Rochers and Peace Rivers (unknown to simulation)

Q_P flow in Peace River above the confluence with the Quatre Fourches (known to simulation)

Net Evaporation (feet/day)

RAINEV - net evaporation

Water Levels (elevation above sea level)

ELAKE - Lake Athabasca water level

G_F Water level (gauge height) at the Peace, Quatre Fourches confluen

G_R Water level (gauge height) at the Peace Rochers confluence

Storage (acre feet)

S Storage in Lake Athabasca at level ELAKE

Area (acres)

A Area of Lake Athabasca at level ELAKE

Routing Period (days)

L Time period from the start of routing

ΔT Routing period used - one day. A period longer than one day should only be used for those periods when the water levels at the Peace - Quatre des Fourches and Slave - Chenal des Rochers are not changing appreciably from day to day.

Iteration Counters

J Jth iteration on outflow determination at fixed lake level

K Kth iteration of lake level determination

B/ Lake Athabasca Routing Equations (See Athabasca Delta Project Report #1 for the actual form of the following functions)

i. Flow Relationships (open water, natural conditions)

$G_R = F_{GR}\ (Q_S)$ i.e. G_R is a function (F_{GR}) of Q_S

$Q_R = F_{QR}\ (ELAKE, G_R)$

$G_F = F_{GF}\ (Q_S, Q_P)$

$Q_F = F_{QF}\ (ELAKE, G_F)$

ii. Storage Elevation Relationship

$ELAKE = F_{ES}\ (S)$

iii. Area Elevation Relationship

$A = F_{AE}\ (ELAKE)$

iv. Changes to Flow Relationships for Outflow Controls

(a) Weir dams, constriction etc. on the Slave - F_{GR} and F_{GF} are modified.

(b) Weirs, dams, etc. on the Riviere des Rochers - F_{QR} is modified

(c) Weirs, dams, etc. on the Chenal des Quatre Fourches - F_{QF} is modified.

v. Changes to Flow Relationships for Ice Conditions

Possibility #1 - Daily corrections (see Figure 1)

BWA - Difference between actual winter gauge height and open water gauge height of Peace-Quatre Fourche confluence

BWB - As BWA but on the Slave-Rochers confluence

Note: It was assumed BWA = BWB = BW1 = Difference between actual winter gauge height and open water gauge height for flow Q_P of the Peace River at

Peace Point gauging station. BW1 is strongly dependent on ice thickness (≈ 0.9 x ice thickness) during most of the winter season. It is affected by Q_S and Q_P to a small degree but this has been neglected.

BWC - Difference between the open water gauge height at Peace Quatre Fourches confluence and G_F plus BW1 for given Q_P, Q_S, Q_R, Q_F

BWD - Difference between the open water gauge height at the Slave Rochers confluence and G_R plus BW1

It was assumed BWC = BWD = BW2 because information was only available in the winter for the sum of $Q_R + Q_F$.

then, $G_R = F_{GR} (Q_S) + BW1$

$Q_R = F_{QR}$ (ELAKE, G_R + BW2)

$G_F = F_{GR} (Q_S, O_P) + BW1$

$Q_F = F_{QF}$ (ELAKE, G_F + BW2)

This method did not converge in the majority of cases.

Possibility #2 (see Figure 2)

If $Q_R = F_{QR}$ (ELAKE + BW)

$Q_P = F_{QR}$ (ELAKE + BW)

under winter conditions, where the new functions are determined for ice conditions, then BW is the daily fluctation required to make the relationships exact on a daily basis.

vi. Determination of Outflow in Chenal des Quatre Fourches and Riviere des Rochers Channels from Outflow Relationships

This procedure can be represented as

(Q_R, Q_F) = PROC (ELAKE, Q_P)

That is, given a lake elevation and Peace River flow, the values of Q_R and Q_F are to be determined.

Since the Slave River flow is required in the outflow relationships to determine water elevations at the two confluences, and since it is initially unknown, an iteration technique is required to determine the outflow. Thus we have (counter = J):

$$Q_{S,J} = Q_P + Q_{R,J-1} + Q_{F,J-1}$$

$$G_{R,J} = F_{GR}(Q_{S,J})$$

$$Q_{R,J} = F_{QR}(ELAKE, G_{R,J})$$

$$G_{F,J} = F_{GR}(Q_{S,J}, Q_P)$$

$$Q_{FJ} = F_{QF}(ELAKE, G_{F,J})$$

$$\left|(Q_{R,J-1} + Q_{F,J-1}) - (Q_{R,J} + Q_{F,J})\right| < \epsilon_1 ?$$

if not, $Q_{F,J} = (Q_{F,J} + Q_{F,J-1}) /2$ (modified bootstrapping)

and $Q_{R,J} = (Q_{R,J} + Q_{R,J-1}) /2$

Note: ϵ_1 is an error criterion

Repeat procedure incrementing J by 1 until error criterion is satisfied. Note that Q_{RO} and Q_{FO}, the initial values, are set equal to the outflows determined in the previous set of iterations.

vii. Routing Procedure

The reservoir routing procedure used is also bases on a modified bootstrapping iteration (counter = k):

$$(Q_{R,K,L}, Q_{F,K,L}) = PROC\ (ELAKE_{K-1,L}, Q_{P,L})$$

$$S_{K,L} = S_{L-1} + (I_{L-1} + I_L - (Q_{R,L-1} + Q_{F,L-1} + Q_{R,K,L} + Q_{F,K,L})) \frac{\Delta T}{2 \times 1.98} + RAINEV_L - A_{K,L}$$

$$ELAKE_{K-1,L} = F_{ES}(S_{K,L})$$

$$\left|ELAKE_{K-1,L} - ELAKE_{K-1,L}\right| < \epsilon_2 ?$$

If not, $ELAKE_{K,L} = (ELAKE_{K,L} + ELAKE_{K-1,L}) /2$

ϵ_2 is an error criterion (= .005 feet)

Note that ELAKE $_{O,L}$ (the initial estimate at the beginning of each iteration is assumed to be the lake level of the previous time period L-1 i.e. $ELAKE_{O,L} = ELAKE_{L-1}$). As previously mentioned, the first initial values of $Q_{R,L}$ and $Q_{F,L}$ are equal to the outflows of the previous time period. Thereafter, these initial values are equal to the outflows determined for the previous value of k.

POSSIBLE FUTURE REFINEMENTS

(a) If inflows could be separated with accuracy, the system could be divided into 2 or more interconnected lakes with this type of routing procedure.

(b) Binary Search

If it is found that the modified bootstrapping procedure does not converge for ice period simulation because of unstable outflow relations, a combination of this procedure and binary search is recommended. This algorithm was used by the author on the Gull Lake pump design where stepping functions caused non-convergence.

(c) Weir and Dam Selection

By proper selection of crest elevation, weir or notch width and location(s) it is probably possible to control the lake levels to a satisfactory degree (see table 1). This could be best ascertained for a given design by analysing the resulting hydrographs of lake levels over the maximum possible period of simulation with the biological model presently under development. It is, of course, possible to integrate the biological model into the simulation model directly, and to optimize the biological benefits through changes in the design parameters determine by an optimization technique.

(d) Combinations of Controlled (gated) and Uncontrolled Outlets

If, on the basis of the biological model and channel regime studies, it is found that a gated structure is necessary, this routing technique can be applied to a combination of control and uncontrolled outlets. The technique has previously been applied under these circumstances

to the Pembina River Dam Study, to the Gull Lake Pumping proposals and in the CGE timesharing program.

(e) Net Evaporation

If net evaporation for actual conditions is determined as part of the inflow, some inaccuracy will exist when, during simulation with structures, the lake area is appreciably different than it was under natural conditions for the same time periods. This can be overcome by finding the difference in lake areas between that determined by routing and that which actually occurred. Then, even though net evaporation is poorly known, the overall volumetric error in net evaporation will not be large, since the differences in lake areas will be small relative to total lake area.

TABLE I

LAKE ATHABASCA ELEVATIONS IN 1969 WITH CONCRETE WEIRS

ON THE ROCHE CHANNEL

(An illustration of the extent to which weirs can raise Lake Athabasca Levels)

DAY in 1969	Actual	Crest Elevation 680' Width 800'	Crest Elevation 683' Width 700'
June 1	685.77	685.77	685.77
July 1	684.97	686.05	686.73
Aug. 1	684.13	685.70	686.88
Sept. 1	683.36	685.49	687.00
Oct. 1	682.59	685.09	686.80
Nov. 1	682.05	686.71	686.56
Dec. 1	681.88	684.23	686.32
Jan. 1	--		686.09

Note (a) The outflow formula assumed was $Q_R = 4.0W\ (\text{Lake elevation-crest elevation})^{3/2}$

(b) Actual levels with the weirs will be slightly higher in December because of the restricting effects of ice cover, which were not considered in the above simulation.

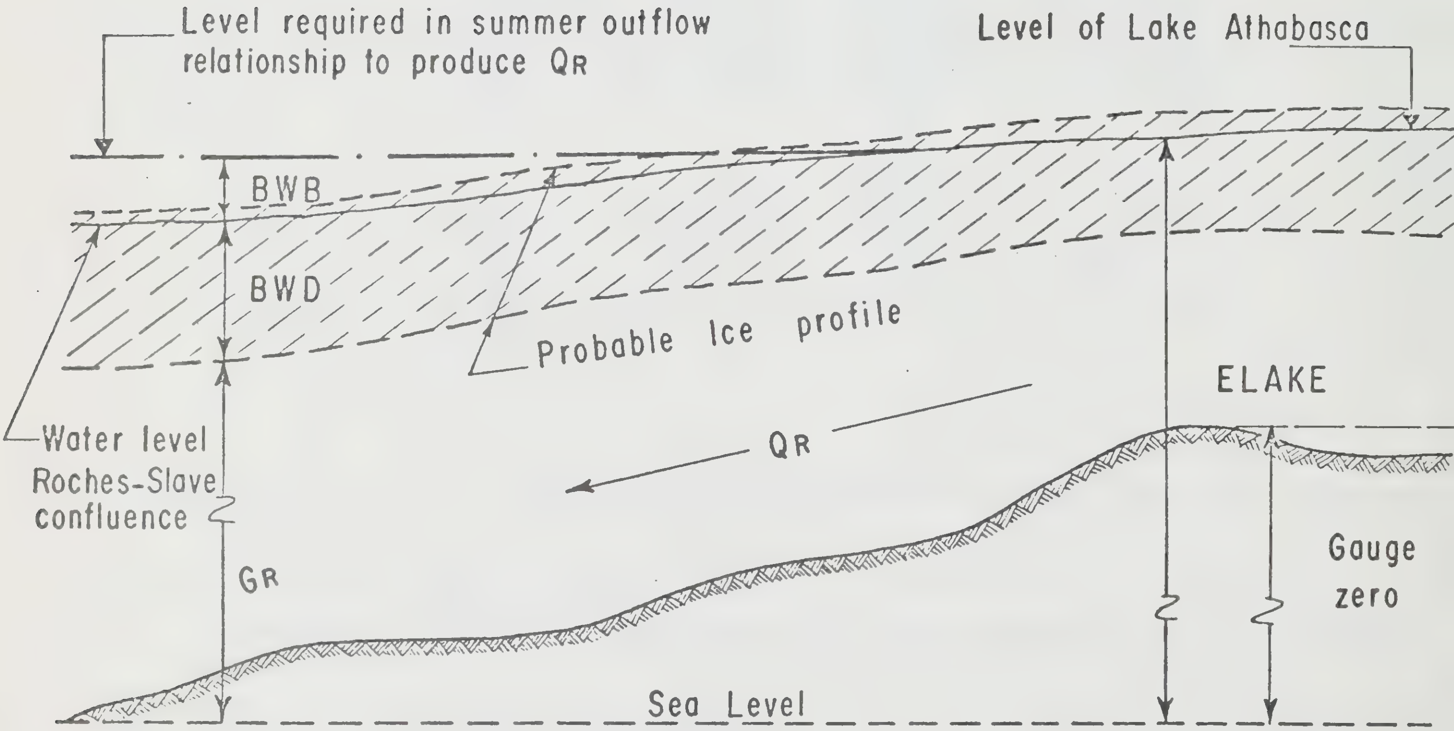
APPENDIX C-1

FIGURE I

ICE CONSTRAINED OUTFLOW

CHANNEL DES ROCHES

(POSSIBILITY I)



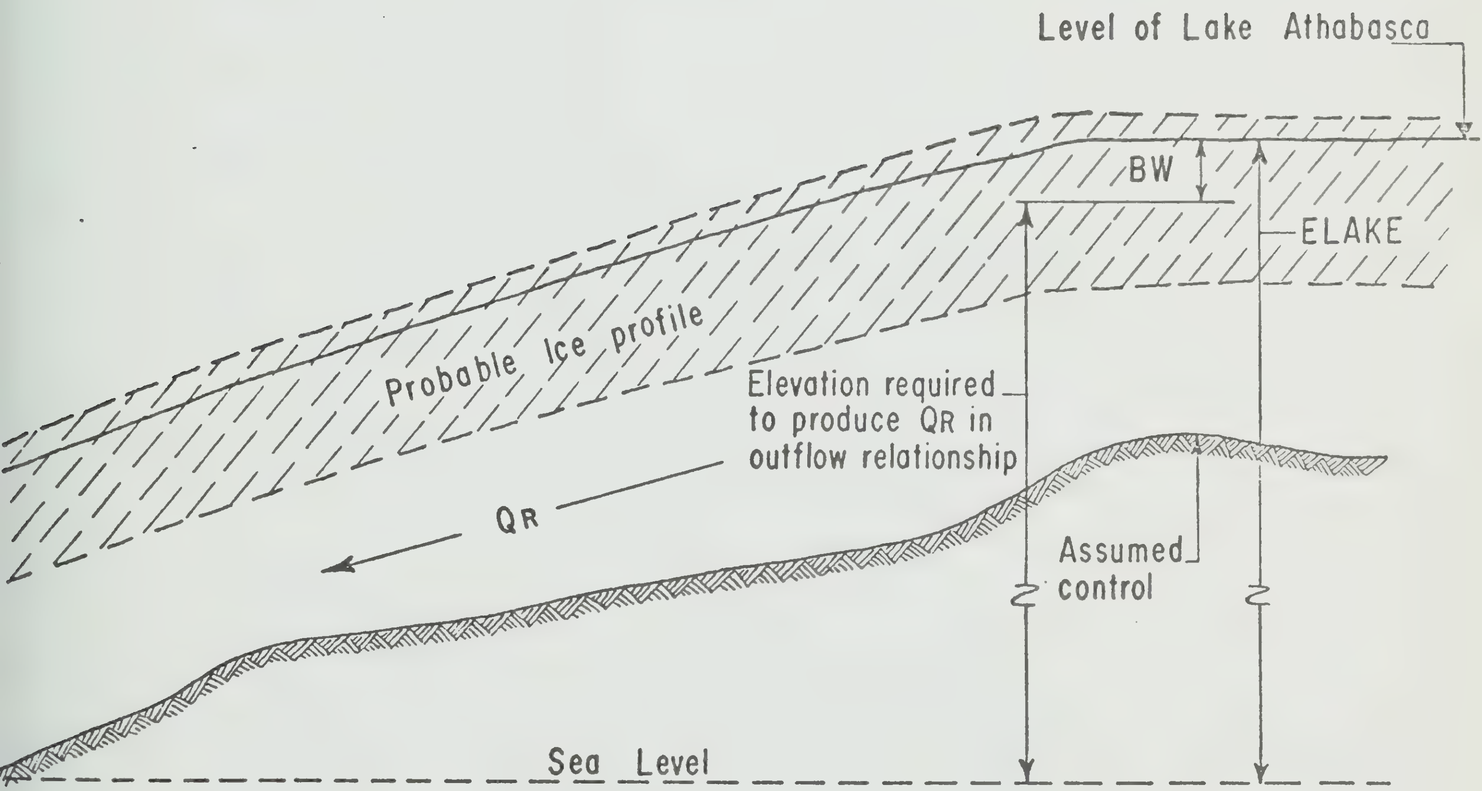
APPENDIX C-1

FIGURE 2

ICE CONSTRAINED OUTFLOW

CHANNEL DES ROCHES

(POSSIBILITY 2)



SECTION D

S E C T I O N D

PEACE RIVER FLOWS

AND THEIR EFFECT

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Edmonton
1972

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D-2 Monthly Mean Discharge on Peace River at Peace Point and Hudson Hope. 11

PEACE RIVER FLOWS & THEIR EFFECT

Introduction

Lake Athabasca is drained through two channels, the Riviere des Rochers and the Chenal des Quatre Fourches, both of which join the Peace River. The Rochers carries 90 percent of the outflow. The volume of water draining out of the Lake is in proportion to the level of water in Lake Athabasca and to the level of the water in the Peace River. The water normally flows north in these channels toward the Peace River, but reverses its direction of flow when the water level in the Peace rises higher than the level of Lake Athabasca. During most spring floods, the water level on the Peace River has risen sufficiently to retard or reverse the flow out of Lake Athabasca, resulting in a back-up or storage of water in the Lake which, in turn, spills out to flood the Delta.

If spring flood waters are held in the Lake, the Delta will be inundated. If these waters are permitted to flow rapidly out of the Lake, very little flooding occurs on the Delta.

Low Flows on the Peace River

The cause of low water in Lake Athabasca and the Delta can be largely attributed to a reduction in Peace River flows since 1968. Prior to 1968 the Peace River experienced flood flows averaging 311,000 cubic feet per second or greater for 10 days usually in June in the vicinity of the Delta, which were sufficient to prevent water from flowing out of the Lake Athabasca and Delta system, and oftne created a southward flow of water which added to the volume of water in the system. In December of 1967 the

Bennett Dam was closed and the filling of Williston Lake behind the dam began. Even though the dam is located some 730 miles upstream from the Delta, it effectively controls 50% of the flow in the Peace River at its point of influence on Lake Athabasca. During the four years 1968-71 there was a net storage in Williston Lake of 50 million acre-feet of water (Figure D-1). The actual discharge through the dam during the filling of the reservoir is depicted also for the Peace River near Hudson Hope, B.C., which is 30 miles downstream from the Bennett Dam. The natural flow at Hudson Hope, also shown, was computed from data based upon the operation of the reservoir. Clearly, the effect of the closure of the dam has been to capture most of the flow, particularly the large volume of summer run-off from the upper regions of the Peace River, allowing only a very low flow to pass.

Flows on the Peace River in the vicinity of the Delta were also monitered at Peace Point. A considerable amount of water enters the Peace River downstream from the Bennett Dam and the pattern of actual flow at Peace Point reflects this additional discharge (Figure D-1). Standard stream-flow routing procedures were used to reconstruct the estimated natural flow at Peace Point (see Appendix D-1). Flood flows on the Peace River adjacent to the Delta were reduced by as much as 200,000 cubic feet per second, and this reduction in flows meant that the river levels were as much as 10-12 feet lower than they would have been without regulation. The low levels on the Peace River permitted water to flow out of Lake Athabasca much more rapidly than normal during spring and summer. Table D-1 presents a summary of the Peace River flows and Lake Athabasca outflows

for the four years 1968-71 and mean values for the 1960-67 period.

The bottom graph in Figure D-1 depicts the actual level of Lake Athabasca and the estimated natural level if the Bennett Dam had not been in existence. The difference between the two hydrographs is the estimated effect of the Bennett Dam. Without the dam, in 1968 the levels would have exceeded 688.0 instead of reaching only 684.5. During 1969 and 1970 the natural level would have reached or exceeded 687.0 and during 1971 Lake Athabasca should have peaked close to 690 feet. Thus, during the filling phase of the Williston Reservoir the water levels of Lake Athabasca remained an average of 2.5 feet lower than under undisturbed conditions. The waters of the Peace-Athabasca Delta underwent similar declines due to their relationship with Lake Athabasca.

THE W.A.C. BENNETT DAM

The history of the W.A.C. Bennett Dam goes back to 1956, when the Province of British Columbia signed an agreement with the Swedish Wenner-Gren firm to conduct resource and development surveys in northeastern British Columbia, including the upper Peace River basin. A major result of this survey was the 1959 Feasibility Report on the Peace River Hydro-Electric Project, which indicated the possibility of building two hydro-electric generating facilities on the Peace River, just west of Hudson Hope. Together, the two sites would have a potential electrical output of 3,185 megawatts of power, equivalent to 4¼ million horsepower.

In August 1961, the government of the province acquired ownership of the

B.C. Electric Company and the Peace River Power Development Company, which had been formed as a result of the Feasibility Report. The newly formed Crown corporation, the B.C. Hydro and Power Authority ordered an immediate start on the upstream site and designated it the Portage Mountain Development. This project became the W.A.C. Bennett Dam, the Gordon M. Shrum Generating Station, and Williston Lake. This was the larger of the two hydro electric facilities outlined in the 1959 Feasibility Report and was constructed with a capacity to produce 2,270 megawatts of power (3 million horsepower).

The Bennett Dam, 600 feet high, creates Williston Lake which has a volume of 57,000,000 acre-feet of water. It is one of the world's largest man-made lakes, covering an area of 635 square miles, and over 200 miles in length. The dam, also one of the largest of its type in the world, contains some 57,000,000 cubic yards of fill material and is termed a zoned earth-fill type of dam.

The Shrum Generating Station is a large underground powerhouse with an ultimate complement of ten generating units, each with a nameplate rating of 227 megawatts. At present, seven of the ten units have been installed and normal procedure requires five of the units to be in operation at any one time. Each unit discharges about 6,000 cubic feet of water per second when in operation. In addition to discharges from the generating station, water can be released by the W.A.C. Bennett Dam over the main spillway. The rate of discharge is dependent upon the reservoir level, but with the reservoir at its maximum operating elevation of 2,205 feet, the spillway

could pass approximately 250,000 cubic feet per second.

It took about 5½ years to build this power complex, and as construction reached the final stages in December of 1967, the dam was closed and the upper Peace River came under the control of man.

Future Flows on the Peace River

Because prediction of future precipitation and streamflow is not possible with present technology, an assessment of future water levels must be based on the assumption that the future will be similar to the past. As described in Section C, historical water levels in the period 1960-71 have been successfulyy reproduced with a simulation model. This model permits a manipulation of Peace River flow data so that an assessment can be made of the effect of changes in the flow on the levels of Lake Athabasca. Therefore, by inserting the anticipated future Peace River flow as modified by the Bennett Dam into the model for the years 1960-71, it is possible to simulate Lake Athabasca levels which reflect the modified Peace River flow. The result is a water level record for a 12-year period in the past which illustrates the effect of the Bennett Dam for that period.

Monthly releases in cubic feet per second were provided by the British Columbia Hydro and Power Authority for each month of the year. The percentage of the total annual release was determined for each month and applied to the mean annual flow for the period 1960-70 to obtain the actual flow releases assumed in this study. It was assumed that there

would be full utilization of inflow to the reservoir for power generation; therefore, no additional flow due to spillway releases was considered to have occured during the 12-year period from 1960-71 for which Lake level hydrographs were simulated. Five-day values were assumed to be the same as monthly values except at month ends, where an adjustment was made to average the flow volume of a five-day period extending into the next month.

Preliminary estimates covering a range of future releases from the W.A.C. Bennett Dam were sent to the federal government in January of 1971 and all available estimates including those used in the model are given in Table D-2. At some time in the future, these values may be modified by a diversion of water into Williston Lake from the McGregor River basin. The addition of this water would increase the average annual flow available at the Bennett Dam by about 18%. The McGregor River diversion has not been included in any of the following calculations.

The effect that the regulation of flows will have on the Peace River is illustrated graphically in Figure D-2. The monthly mean flow for June will decrease from 145,000 cubic feet per second to 35,000 cubic feet per second at Hudson Hope just downstream of the dam. At Peace Point, Alberta, a few miles upstream of the Delta, the regulatory effect of the dam will create an estimated mean June flow of 150,000 cubic feet per second, which is some 110,000 cubic feet per second lower than the natural value. This difference in flow means that the level of the Peace River in the vicinity of the Delta will be approximately 10 feet lower in June than it was naturally.

TABLE D1 Peace River Flows and Lake Athabasca Outflow

Year	Peace River 5-Day Max. Flow cfs	Mean Flow for June cfs	Lake Athabasca Outflow during May, June July acre-ft.
1960-67 mean	326,000	266,000	3,400,000
1968	156,000	114,000	11,400,000
1969	197,000	76,100	14,000,000
1970	118,000	98,800	11,700,000
1971	202,000	115,000	10,770,000

TABLE D2 Peace River Flows

ALTERNATIVE ESTIMATES OF FUTURE W. A. C. BENNETT DAM RELEASES

	Based on B.C. Hydro & Power Authority Letter to Alberta Research Council (July 20, 1970)		Based on B.C. Hydro & Power Authority Letter to Federal Government (January 1971)						Used by PADP for Base Yr. (average)	
			Dry Sequence		Median Sequence		Wet Sequence		Annual Flow 1960-70	
	cfs	%	cfs	%	cfs	%	cfs	%	cfs	%
January	41,300	9.4	32,370	8.4	40,420	8.9	43,580	9.0	45,000	9.4
February	40,400	9.2	39,140	10.2	46,230	10.1	52,440	10.8	44,000	9.2
March	39,700	9.0	34,980	9.1	42,640	9.3	47,360	9.7	43,500	9.1
April	37,700	8.6	32,690	8.6	42,230	9.3	46,010	9.5	41,000	8.6
May	33,200	7.6	27,910	7.3	35,980	7.9	39,790	8.2	36,000	7.5
June	32,500	7.4	27,690	7.2	35,430	7.7	39,640	8.2	35,500	7.4
July	31,400	7.1	27,540	7.2	33,760	7.4	37,420	7.7	34,500	7.2
August	33,200	7.6	30,510	8.0	35,530	7.8	36,940	7.6	36,000	7.5
September	36,000	8.2	34,220	8.9	38,550	8.4	38,670	7.9	39,000	8.2
October	36,500	8.3	33,120	8.7	33,760	7.4	32,680	6.7	40,000	8.3
November	37,700	8.6	32,300	8.4	35,340	7.7	34,750	7.1	41,000	8.6
December	39,700	9.0	30,510	8.0	36,870	8.1	36,940	7.6	43,000	9.0
Annual Average	**36,600**	**100.0**	**31,915**	**100.0**	**38,054**	**100.0**	**40,520**	**100.0**	**39,875**	**100.0**

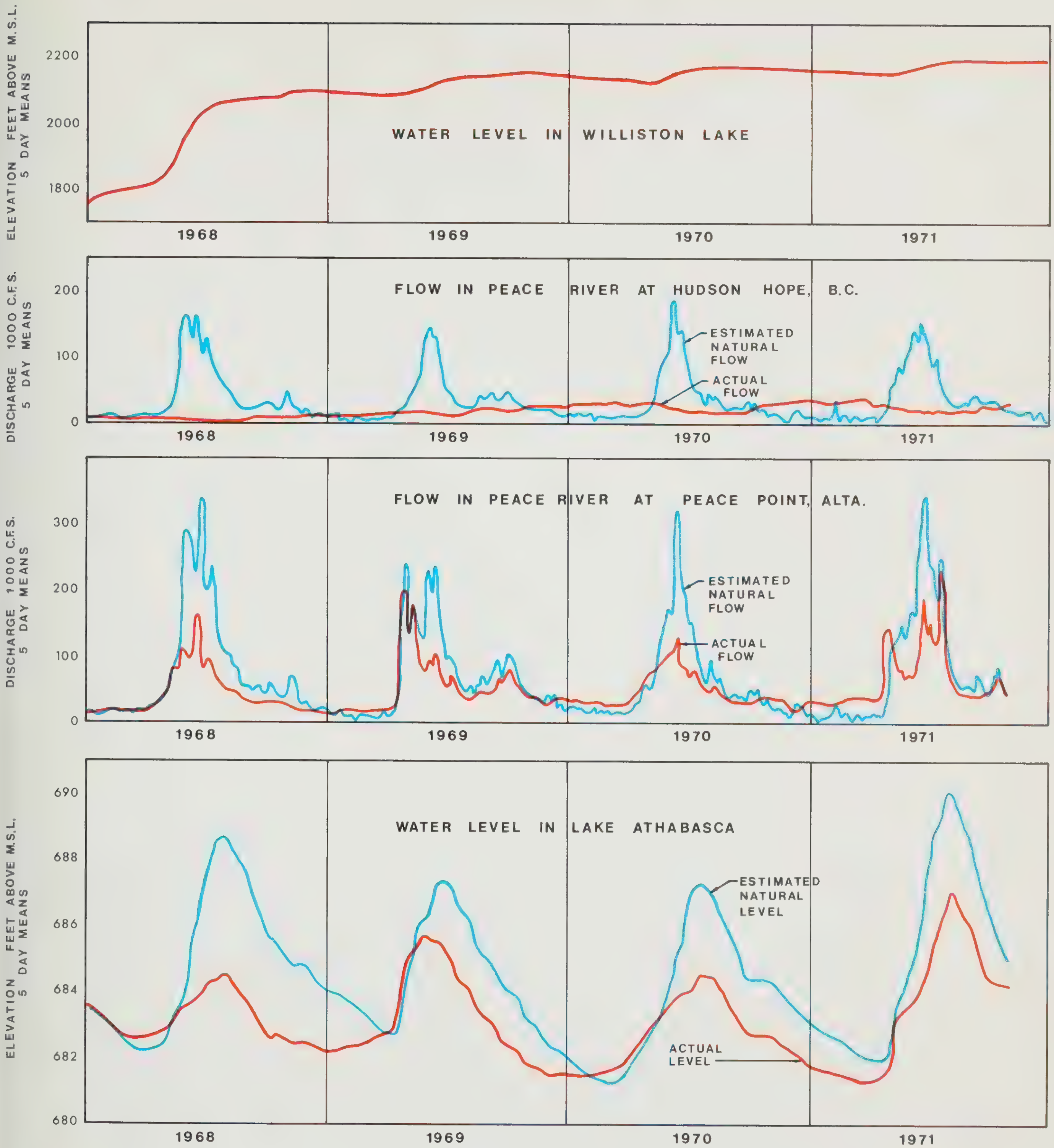

FIGURE D-1 Williston Lake Levels, Peace River Flows, and Lake Athabasca Levels 1968-71. Observed values and estimated natural values

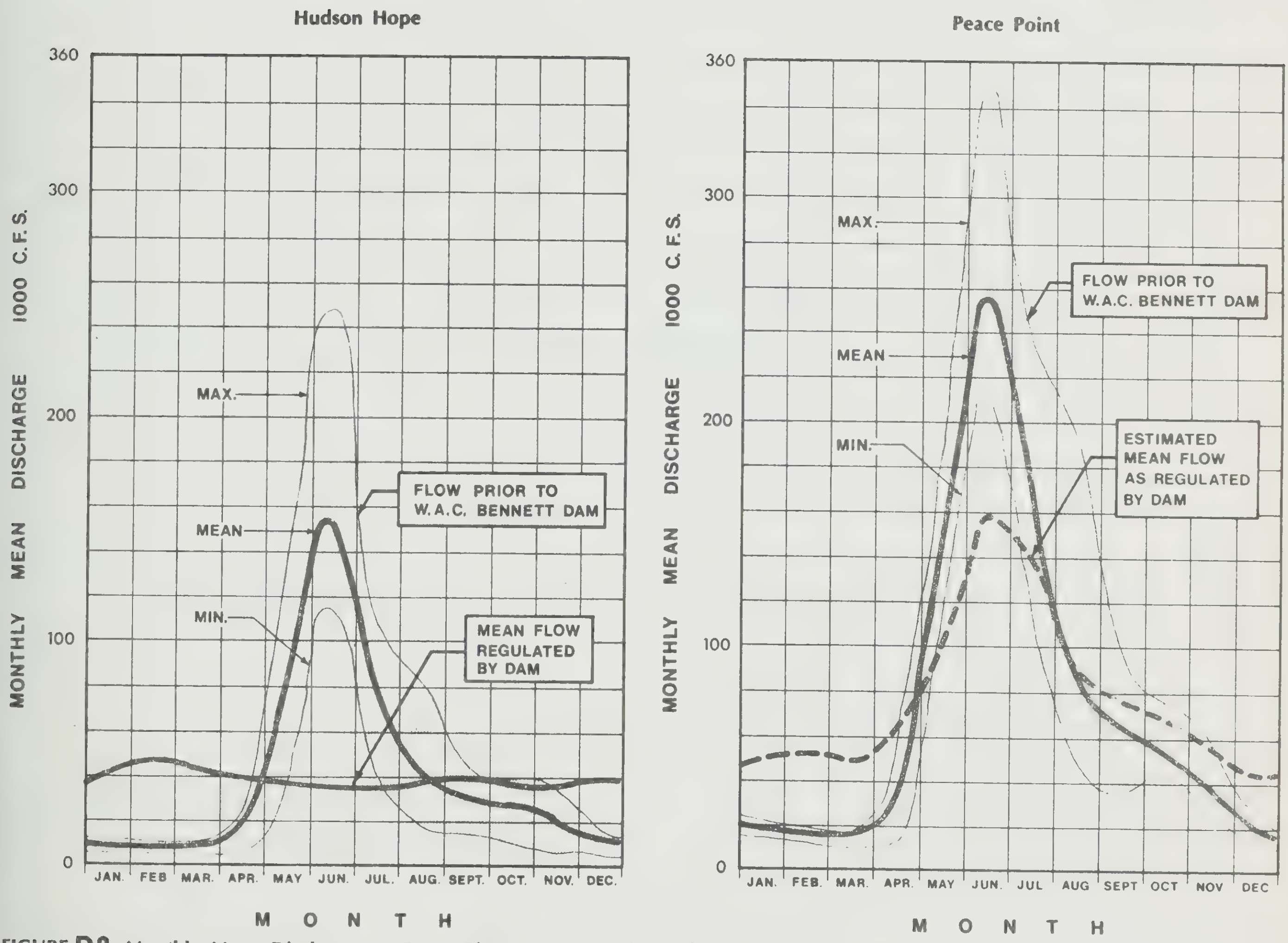

FIGURE D2 Monthly Mean Discharge on Peace River at Peace Point and Hudson Hope

APPENDIX D-1

PEACE RIVER at PEACE POINT
ROUTING PROCEDURE

Peace River at Peace Point

Routing Procedure

Estimates of natural flow (daily values) for Peace River at Peace Point were made by routing flows from Hudson Hope down to Peace Point. Because of regulation by the Bennett dam, Hudson Hope flows were developed by using the storage-volume curve for Williston Lake (Portage Mountain Development, Report Serial No. 548, Figure 2, Drawing No. 1006-C14-A97, July 1970) and applying recorded mean daily elevations every fourth, fifth, sixth or seventh day. The net change in storage for each four, five, six, or seven day period was deemed to represent the net mean inflow or outflow for that period. By adding or subtracting the mean daily flows to the recorded flow at Hudson Hope, natural flow for Hudson Hope was estimated.

The following tributaries were used to generate the flow for Peace Point:

Halfway River near Farrell Creek
Pine River at East Pine
Beatton River near Fort St. John
Smoky River at Watino
Wabasca River above Junction Peace River 68, 69, 70
Wabasca River at Wadlin Lake Road 70, 71

By summing the daily flows for Hudson Hope, Halfway River, Pine River and 20 percent of Pine River to account for local inflow an estimate for Peace River at Taylor was obtained. To the flow at Taylor, flows for Beatton River near Fort St. John were added. Eighty and twenty percent of this total were lagged for 1 and 2 days respectively. This procedure is based upon the method of successive averages. Daily flows for the Smoky River plus 40% of the flow (to account for local inflow) were added to the lagged values to give an estimate for Peace River at Peace River. Peace River at Fort Vermilion is estimated by lagging Peace River at Peace River by 2 days, no local inflow

is assumed. The Wabasca is added to Fort Vermilion flows and then lagged for 2 days to provide the estimate for Peace River at Peace Point.

Method of Successive Averages

The procedure used was developed by Tatum* and is a arbitrary weighting system which assumes that there is a point downstream from a station where a discharge at time t_2 is equal to $(I_1 + I_2)/2$.

To produce outflow at a specific point downstream, coefficients for successive inflows are selected by trial and error using actual inflow and outflow hydrographs as a test. Tatum had produced original sets of coefficients, in groups of 1 to 10, each group summing to 1. The number of coefficients used depended upon the number of routing steps within the reach.

Points to consider in the use of these predictions.

1. The routing method was tested for the years 1966 and 1967 while unregulated flows at Hudson Hope were available, while natural flows for Hudson Hope had to be developed from the storage relationship for Williston Lake. A comparison of the recorded vs the calculated values of flow for Peace Point 1966 and 1967, shows some discrepancy of peak values. But the major differences are not those of flow magnitude but rather that of the time of occurrence.
2. While the lake levels for 1968, 1969 and 1970, are mean daily values, instantaneous values had to be used for 1971. These have created a situation whereby the change in elevation between each time period can translate into a flow (mean) which can be considered unrealistic for

*Tatum, F.E., A Simplified Method of Routing Flood Flows through Natural Valley Storage, unpublished memorandum, U.S. Engineers Office, Rock Island, Ill., May 29, 1940.

the time of year.

3. Where incomplete records exist, as in the case of the Wabasca River, estimates for the missing data have been included in order to provide a "complete" record. This situation occurred in 1969 and 1970 and the days involved have been marked as estimates.
4. Because of the use of 4, 5, 6 and 7 day mean values, to estimate natural flow at Hudson Hope, the routed Peace Point flows have tended to be grouped, particularly for the lower flows, where there is little change in day to day flows.

SECTION E

S E C T I O N   E

FUTURE WATER LEVELS

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Edmonton
1972

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FUTURE WATER LEVELS

The estimated changes in the Peace River as outlined in Section D, have been translated into levels of Lake Athabasca and in Figure E-1 the resulting hydrographs are presented. One hydrograph illustrates the simulated Lake levels as they actually occurred from 1960 to 1971. The other hydrograph shows the simulated Lake levels which would have resulted if the Bennett Dam had been fully operational since 1960. The four-year period 1968-71 contains a third hydrograph which is a simulation of Lake levels without the effect of the dam, and is therefore an estimate of the natural water level.

A comparison of these two hydrographs illustrates the considerable influence regulation of the Peace River flow exerts on Lake Athabasca levels. During the years 1960 to 1967, prior to regulation, peak levels during the early summer ranged from E. 689.0 feet to El. 691.0 feet. These peaks are reduced by about 1 to 3 feet as a result of flow regulation, while minimum lake levels which occur during the early spring are increased by from 1-½ feet. This is the expected general result of flow regulation since the decrease in spring flows in the Peace River allows increased outflow from Lake Athabasca, and the increased low winter flows impede outflow from the lake. A summary of these differences is presented in Table E-1.

The years 1968 to 1971 illustrate the difference in lake levels between the fully regulated condition and the transitional regulated condition during the filling of the reservoir and the staged installation of the generation units. The degree of severity of the transition condition is

clearly shown, with lake levels of up to 2 feet lower than for the expected future long-term regulated condition.

Figure E-2 presents the hydrographs of mean Lake levels under both natural conditions and the modified conditions due to the Bennett Dam for the 12-year period 1960-71. Under the modified regime Lake levels are considerably lower during the summer months and peak Lake levels average two feet lower than the natural levels. A statistical analysis (Figure E-3) of the peak Lake levels confirms that the levels of the modified regime will produce a considerably different and lower flooding mechanism on Lake Athabasca and the Delta.

EFFECTS ON CHANNEL REGIME

The channel network linking Lake Athabasca and the Peace River has been formed as a result of the external hydraulic conditions imposed upon it and as these conditions change the channels will tend to adapt to new conditions. Construction of the W.A.C. Bennett Dam on the Peace River and subsequent regulation of the Peace River flows has resulted in a significant change in the regime conditions for the Athabasca Delta network. Peak river stages and discharge have been considerably reduced and, since the bulk of sediment transport is associated with high discharge, sediment load has also likely been decreased.

The delta channels have, in general, been cut through silt or fine sand and silt material. Scour velocities for material of this type normally range from 2 to 3-½ feet per second, but the degree of scouring and

sediment transport greatly depends on channel geometry and also flow characteristics. Also of significance in the regime conditions of the channels is the presence of highly resistant geological forms such as the bedrock ridges which are known to occur at the rapids on the Riviere des Rochers.

In order to obtain a preliminary assessment of the influence of these changes, together with the effects of subsequent control of the lake stages through control structures on the Slave River or on the Riviere des Rochers, channel velocities for the Chenal des Quatre Fourches were determined. Average channel velocities in the Quatre Fourches for the two years 1961 and 1965 have been determined for the following conditions:

1) Recorded Peace River flows with no structure.
2) Regulated Peace River flows with no structure.
3) Regulated Peace River flows with a gated control structure in the Riviere des Rochers and the gates open.

Figure E-4 and Figure E-5 illustrate the channel velocities estimated to have occurred during these years.

The first condition represents the situation prior to construction of the dam and is used as a reference from which the influence of the regime changes can be gauged. Regulation of the Peace River flows without any remedial control measure results in lower flow velocities both for discharge directed from the lake toward the Peace River and in the reverse direction. For the two years investigated, flow reversal occurred for

the same number of days (55 days in 1961, and 80 days in 1965) under both the recorded and regulated flow conditions, but during different time periods. The average and maximum velocities in the Chenal des Quatre Fourches for the two Peace River flow conditions are compared in Table E-2.

Although flow velocities for the condition of regulated Peace River flows are considerably reduced, this factor would be offset by both the anticipated decrease in sediment recharge from the Peace River and by lower flow depths. Examination of velocities at the downstream (Peace River) end of the Chenal des Quatre Fourches indicates maximum outflow velocities to be slightly higher in 1961 and slightly lower in 1965 under the regulated flow condition than for the natural condition. It is therefore concluded that some scouring of the channel under regulated Peace River flows with no structure may occur but this is not expected to be excessive and would most probably be concentrated at the Peace River end of the channel.

A much greater degree of scouring on the Chenal des Quatre Fourches is anticipated for the condition of regulated Peace River flows with the Riviere des Rochers gated control structure operated with gates fully open. Average and maximum velocities for this condition are included in Table E-2. Reverse flow velocities are considerably reduced and occur for a much shorter period of time (20 days in 1961 and 40 days in 1965) than for the natural condition. Velocities are substantially larger for flows directed toward the Peace River. Maximum velocities at the Peace River confluence are 5.8 and 5.3 feet per second compared with velocities of 3.2 and 3.4

feet per second for the years 1961 and 1965 respectively under conditions prior to regulation.

Scouring of the channel with a control structure on the Riviere des Rochers is therefore anticipated unless resistant geological formations are encountered. Initially this scouring would probably be concentrated at the downstream end of the channel at the Peace River confluence, but would gradually proceed upstream along the channel with a progressively reduced intensity. Over a period of time the discharge capacity of the channel would be increased as the result of this scouring and the effectiveness of the control structure on the Riviere des Rochers to increase lake stages would be somewhat reduced. However, the degree of scouring anticipated should not be sufficient to enlarge the channels to an extent such that the effectiveness of a control structure on the Riviere des Rochers would be seriously impaired.

Although the Revillon Coupe channel was not examined in detail, random velocity calculations indicate velocity conditions similar to those encountered on the Chenal des Quatre Fourches. Maximum velocity at the Peace River end of this channel, however, did not appear to be above 4 feet per second under the conditions of regulated flow with the Rochers gated control structure. Higher lake stages than those encountered with this structure would tend to aggravate the scouring condition.

Regime conditions with the control structures on the Slave River were not examined in detail, but this condition is very similar to the natural condition except for the reduced inflow of sediment laden water from the

Peace River. Hence, only limited scouring is anticipated.

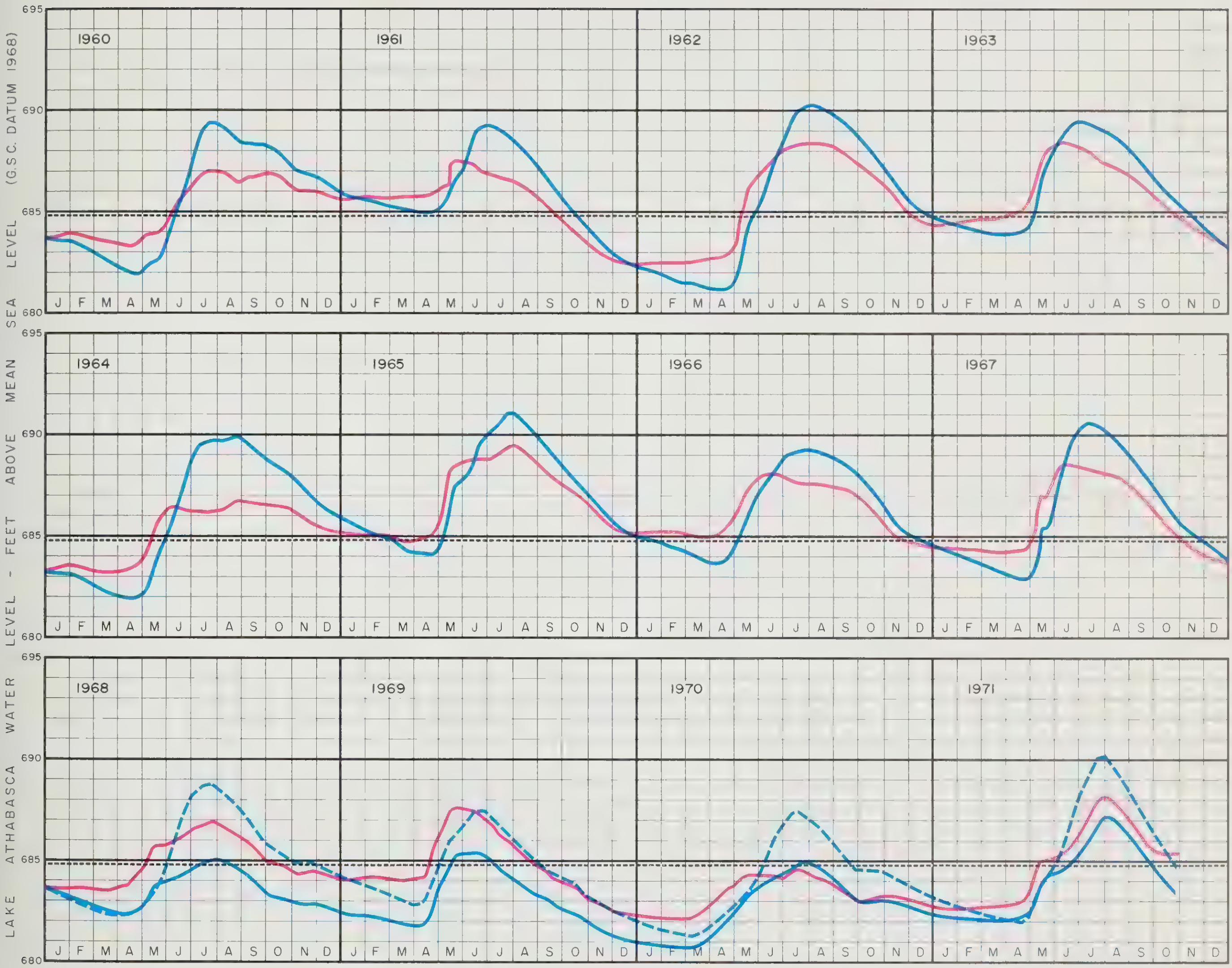
TABLE E 1 Differences in Lake Athabasca Levels* Between the Natural and Modified Regimes

		Natural Lake Level 1960-71	Modified Lake Level 1960-71
May 21-30	(10 day mean)	685.4	686.5
Max. Level	(5 day mean)	689.4	687.6
Time of Max Level		July 15-19	July 5-9
July 11-20	(10 day mean)	689.0	687.0
Aug. 9-13	(5 day mean)	688.7	686.9
Sept. 23-Oct. 2	(10 day mean)	686.6	685.6
Oct. 13-17	(5 day mean)	686.0	685.3
Mean Summer Level (May 16-Aug. 13)		687.9	686.8

*All levels based on simulation model results, and are given in feet above mean sea level (GSC datum, 1968 revision)

TABLE E-2 CHENAL DES QUATRE FOURCHES - VELOCITIES IN FT/SEC

Year/Condition	Flow Toward Peace R.		Flow Toward Lake Athabasca	
	Average	Max.	Average	Max.
1961				
Recorded Peace R. flow No Structure	1.36	2.42	1.53	2.58
Regulated Peace R. flow No Structure	1.12	1.96	0.61	1.04
Regulated Peace R. flow Rochers Gated Structure Gates Open	1.61	2.84	0.79	0.96
1965				
Recorded Peace R. flow No Structure	1.50	2.55	1.30	2.46
Regulated Peace R. flow No structure	1.22	2.33	0.77	1.61
Regulated Peace R. flow Rochers Gated Structure Gates Open	1.70	3.08	0.98	1.50



LEGEND:

- Observed lake levels
- Estimated lake levels assuming no effect by Bennett Dam 1968 to 1971
- Modified lake levels assuming full operation of Bennett Dam
  All Hydrographs derived from computer simulation model
- Approximate average annual lake level (1930 to 1970)

NOTE: Observed levels 1968 to 1971 occurred during the initial filling of Williston Lake and hence are lower than the modified levels.

FIGURE E-1 Lake Athabasca Hydrographs, showing observed, modified, and average water levels

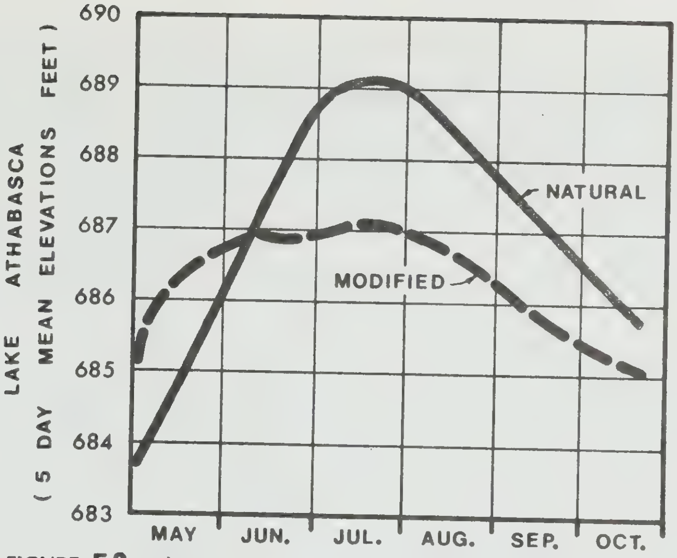


FIGURE E2 Mean Lake Levels (1960-71) for Lake Athabasca, natural and modified regimes

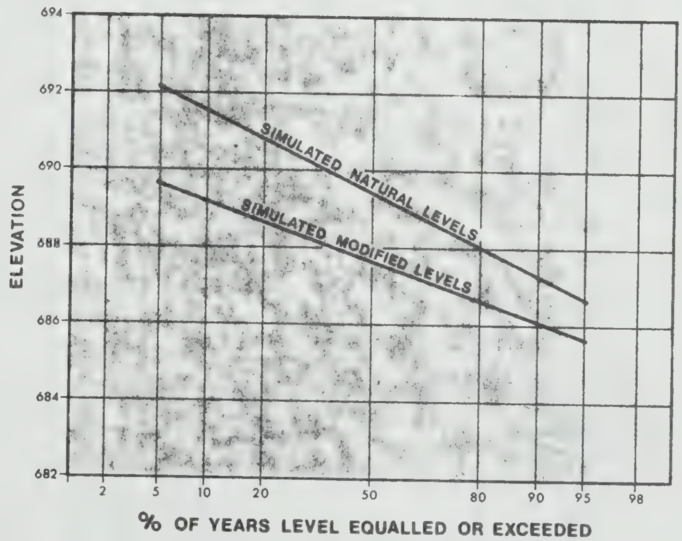
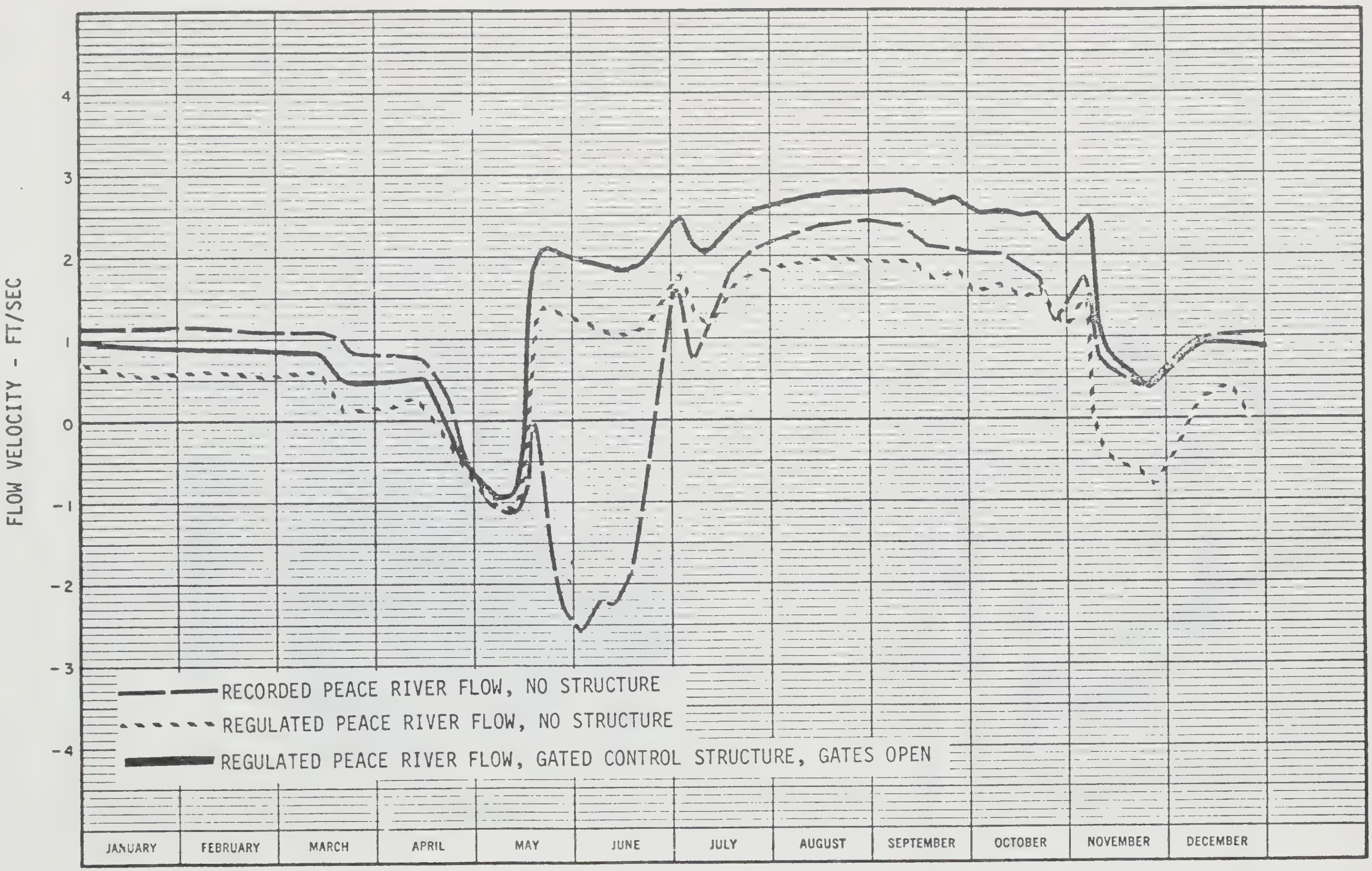


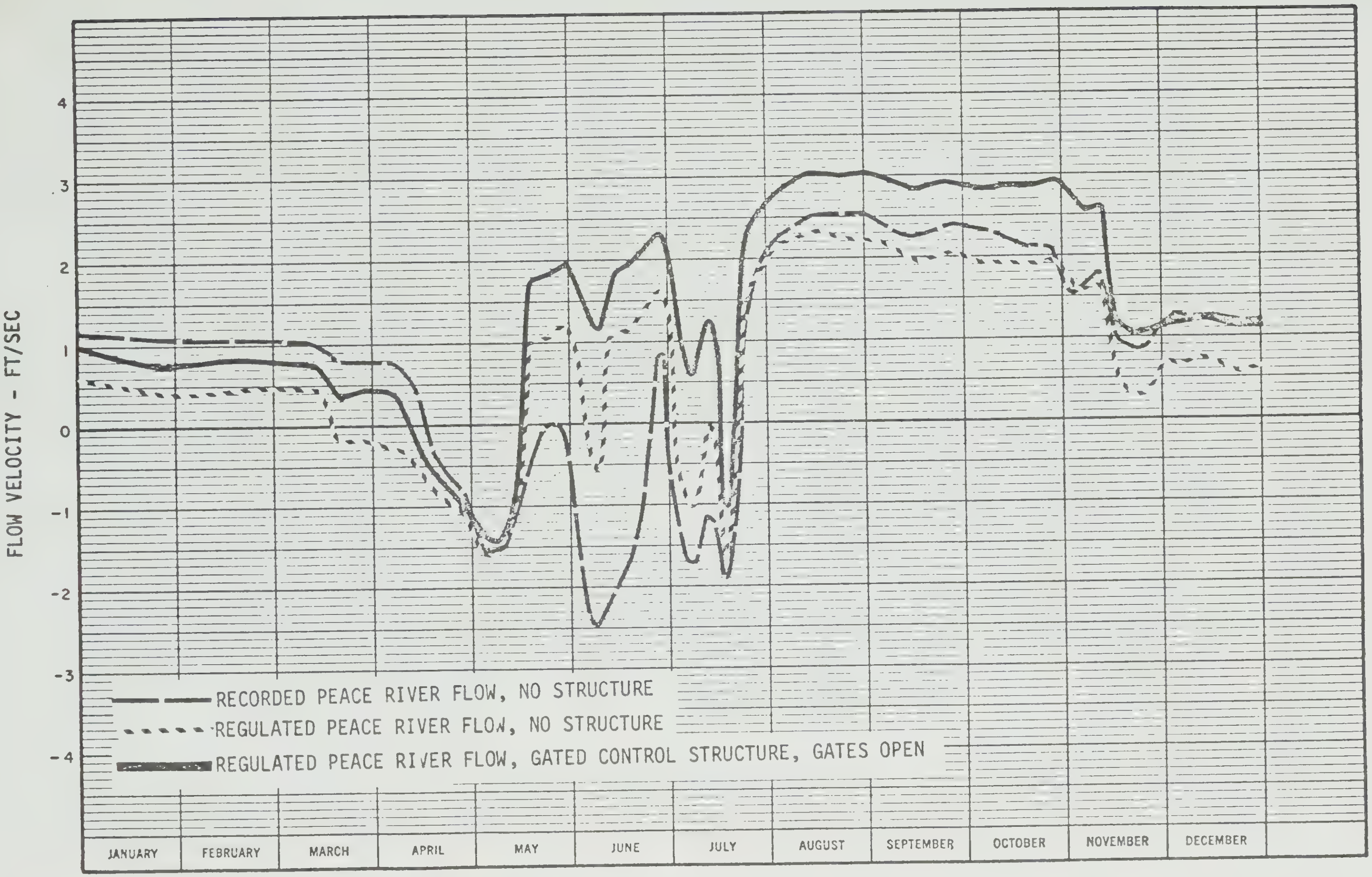
FIGURE E3 Frequency Analyses of Peak Lake Athabasca Levels, natural and modified regimes



CHENAL DES QUATRE FOURCHES

FLOW VELOCITIES - 1961

FIG. E4



CHENAL DES QUATRE FOURCHES

FLOW VELOCITIES - 1965

FIG. E5

SECTION F

S E C T I O N   F

STRUCTURES
FOR
WATER LEVEL CONTROL

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Edmonton
1972

Hydrology Branch
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Edmonton
1972

STRUCTURES FOR WATER LEVEL CONTROL

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STRUCTURES FOR WATER LEVEL CONTROL

DESCRIPTION OF ALTERNATIVE SITES

As discussed in Appendix Q, various locations were considered for providing hydraulic control of the Peace-Athabasca Delta Region. The following sites were chosen by reconnaissance as appearing favorable for structures and these have been shown on Figure F-1.

Site 1 - is located on the Slave River about 5-1/2 miles downstream of its confluence with the Riviere des Rochers, and immediately upstream of a rapids section of the river. Site drilling has indicated that the eastern half of the river channel and abutment is bedrock which dips steeply to the west so that the western portion of the channel is in overburden. There is an extensive outcrop of rock near the east bank which appears favorable as a quarry for a rockfill dam or for concrete aggregate.

Site 2 - is located on the Riviere des Rochers about 10 miles upstream of its confluence with the Peace River, about 6-1/2 miles downstream of its confluence with the Revillon Coupe and about 15 air miles north of Fort Chipewyan. It is immediately upstream of a rapids section. Site drilling has indicated a bedrock channel and there are extensive outcrops of bedrock on both sides of the channel.

Site 3.1 and 3.2 - are located on the Revillon Coupe about 15 air miles northwest of Fort Chipewyan. Site 3.1 is about midway along

the course of the Revillon Coupe, and Site 3.2 about 2 miles further downstream. Sites have been chosen where there are bedrock outcrops on both sides of the channel. At Site 3.1 the channel is narrower than elsewhere on the Revillon Coupe with bedrock on the west abutment and apparently only a thin veneer of silt on the east abutment. No site drilling has been done.

Site 4.1 and 4.2 - are located about 14 air miles northwest of Fort Chipewyan on the Chenal des Quatre Fourches. Site 4.1 is about 7 miles upstream of the confluence with the Peace River and Site 4.2 is about 3 miles further upstream. Bedrock is evident at both sites on the left bank only. No site drilling has been done.

Site 5 - is a complex network of looping channels located near the Lake Athabasca end of Riviere des Rochers, about 6 air miles from Fort Chipewyan. No detailed consideration has been given to locating dumped rockfill or a gated control structure at this site.

A geotechnical survey was undertaken in 1971 by R. M. Hardy & Associates Ltd. to determine the nature of the abutments and river channel, and to locate sources of construction materials. The study was based on air photo interpretation and a field survey, and is described in Section Q.

SITE INVESTIGATION

Program by Gepac, Stanley & Associates Ltd.

The purpose of the drilling program was to establish the foundation conditions in the river channels at Site 1 on the Slave River and Site 2 on the Riviere des Rochers, in order to develop the conceptual design, and preliminary capital cost estimates for the alternative hydraulic control structures. Holes were also drilled on the west bank of the Slave River at Site 1 to establish the type of material to be excavated and foundation conditions for a navigation lock at this location.

The program was carried out from March 13 to 29, 1972, so that the river holes could be drilled off the ice. The drilling guidelines stated that the holes should be drilled through the overburden and about two feet into sound rock, or a maximum of 20 feet into overburden. The location and details of the actual holes drilled are shown on Figure F-2 and Figure F-3. As shown on Figure F-2 some holes on the west bank of the Slave River in the region of the proposed navigation lock were drilled to the approximate El.665. Soil samples were recovered about every five feet in the overburden and sample chippings of rock were also recovered for visual description and a limited program of testing.

Drilling was carried out with a sled-mounted Heli-drill. The drill was easily moved and functioned well, causing no delays for maintenance. The drill utilized a tri-cone bit and air pressure to clear the hole. This system was satisfactory on dry land sites but necessitated the use

of casing when drilling on the river. The samples obtained were disturbed but adequate for soil type identification. Rock samples were pulverized with the size of chips ranging from 1/8" to 1/2". The major difficulty encountered in the actual drilling procedure was the setting of casing in the river bottom sand. The casing would sink into the sand when the bit passed beyond the foot of the casing thus necessitating the drill stem to be removed and additional casing to be set.

The equipment was moved to both sites, overland, and the drilling crew and supervisor were transported to the site each day by air. The support equipment for the drilling was a gasoline powered Bombardier. This machine was used to move the drill rig on the ice, for shelter and to haul fuel. Although this machine worked well a heavier diesel model would have been more useful and probably could have pulled the drill rig over the river ice eliminating the overland move to Site 2.

Access was obtained from the winter road by cutting through the bush consisting of larch and willow trees, with a crawler tractor. The crawler operator could not see over the trees and needed guidance.

The state of the river ice was a constant concern with thickness varying daily and the winter road which was used for access was closed to traffic the day after the equipment was moved out.

The drilling program was completed successfully, without any serious problem. The average daily production was about 4-5 holes and the program was completed in the 16 days from March 13 to 29, 1972.

Meaningful data was collected from all holes drilled and such data together with the results of limited testing have been presented in Table F-1 and Table F-2. The results of the drilling program were adequate to establish the location of concrete structures on bedrock, and the extent of overburden.

The surveyed location, elevation, depth to rock, and hole depth are shown in Figures F-2 and F-3.

Recommendations for Further Investigation

Further drilling and soil testing of overburden will be required at the site of the selected alternative to confirm either bedrock, over the limits of the structure foundation, or the properties of the overburden as a foundation for rockfill or navigation lock foundations. The scour potential of the overburden will need to be investigated so that adequate protection can be provided if required.

Additional surveys will be required at the site selected for further study, including bank profiles in the vicinity of the structure site.

A drilling program similar to the program carried out at Site 1 and Site 2 should be considered for Sites 3.1 and 3.2 on the Revillon Coupe and Sites 4.1 and 4.2 on the Chenal des Quatre Fourches for completeness. However such a program would be difficult to justify since it appears unlikely as a result of the present study that a hydraulic control will be required at these sites. The main reason for proceeding with a

program would be preparedness for reasonably quick action if excessive erosion of these channels does begin to occur. The best time to do the drilling is during the freeze-up period, working off the ice.

Topographic mapping of the delta region would be a desirable aid in the determination of the effectiveness of the hydraulic controls to recreate the annual variable flooding pattern over the delta region, provided the relatively high cost can be justified. The suggested practical contour interval is 4 feet with accuracy for interpolation of a plus or minus 2 feet and spot levels to 1 foot accuracy, plotted at a map scale of 1:5000.

DESCRIPTION OF HYDRAULIC CONTROL STRUCTURES

General

The hydraulic studies indicated that control structures, if required, would be located either at Site 1 on the Slave River or at Site 2 on the Riviere des Rochers. Lake level hydrographs were simulated for alternative control schemes, two on the Slave River and three on the Riviere des Rochers.

Preliminary site reconnaissance indicated rock outcrops at both Site 1 and Site 2. Therefore extensive use has been made of dumped rock to be blasted from nearby quarries. Concrete structures are provided only where support is required for hydraulic control gates and for the navigation lock structures. The quarries also provide a source of rock for processing aggregate.

The conceptual designs for gated control structures have indicated the

use of radial gates. However if a gated hydraulic control is selected for further study, fixed wheel gates with an above deck hoist structure, and steel stoplogs, with an above deck gantry frame and stoplog follower should also be considered in detail. Steel stoplogs may show some initial economy but would provide a cumbersome operating procedure. Fixed wheel gates may be appropriate for the extreme winter conditions, since heating and protection can be more easily accomplished.

Site No. 1 is located on the Slave River approximately 5-1/2 miles downstream of its confluence with Riviere des Rochers as shown on Figure F-2. Preliminary site drilling results indicate that the river bed material consists predominantly of bedrock in the eastern half of the river channel cross-section at the site. The bedrock appears to dip steeply towards the west bank with overburden of mainly silty-sand material.

Site No. 2 is located on the Riviere des Rochers about 10 miles upstream of its confluence with the Peace River as shown on Figure F-3. The site drilling program has indicated that the river bed at this location is bedrock with only traces of overburden.

Generally, the dumped rockfill cross-sections are based on the practical shape which would have taken place as the result of dumping rock into flowing water. The suggested method of construction is designed to make maximum use of smaller sized material, resulting from the quarry operation, although the blasting pattern should be designed to produce large rock of the order of 2 to 4 feet.

All the alternative schemes proposed for the level control of Lake Athabasca consist wholly or partly of rockfill structures. Since construction of these structures in a dewatered channel is not practical they will have to be built by dumping rockfill into the open water. Generally in this type of construction the critical situation occurs only at the final stage of river closure. Fortunately, in all the alternatives under consideration the final closure situation will not occur because in each case a considerable portion of the cross-sectional area of the river channel will remain open for passage of flow during construction of the rockfill structure and therefore the flow velocity will not be greatly increased.

The required rockfill is assumed to be obtained by quarrying at a location near the damsite. It is proposed to incorporate a maximum quantity of quarry-run rock in the main body of the dam to reduce the quantity of the larger rock sizes. In addition to providing a less permeable structure the quarry-run core will also increase the stability of the downstream slopes through reduction of percolation and percolation pressure.

Slave River - Alternative 1A
Rockfill Constriction with Navigation Lock

The general arrangement and details of this alternative are shown on Figure F-4.

The arrangement of this alternative is basically similar to the notched weir suggested previously in a report by the Alberta Water Resources

Division. The weir opening has been moved closer to the east bank so that the remaining waterway will line up with the main river channel. In addition, a navigation lock is provided on the west bank to maintain the barge traffic during open water season. This was considered necessary because the flow velocity through the constriction may exceed 20 fps. The velocity should not exceed 10 fps, for the safe maneuvering of barges. With this arrangement the barge traffic would be re-routed to the west side channel downstream of the structure.

The navigation lock has been sized to accommodate the most likely formation of barges and a towboat passing through the lock, based on consultation with navigation personnel experienced in these waters. Steel sheet piling is proposed for the lock chamber walls since preliminary drilling at the site indicated overburden materials in excess of 50 feet in depth on the west bank. The chamber floor is protected by a thick blanket of filter material and lateral support is provided by tie rods behind the walls and a system of concrete floor beams and horizontal struts.

Mass concrete structures for gates are provided at both ends of the lock chamber. The lock is equipped with miter gates which in the open position fit into wall recesses.

The upstream and downstream approach channels are to be excavated in the overburden materials and the exposed surfaces are to be armoured by heavy rip-rap.

The estimated capital cost of this alternative is $12,800,000 and details of the estimate are presented on Table F-3.

Slave River - Rockfill Constriction - Simulated Lake Levels

The simulated lake hydrograph for the condition of regulated Peace River flow with a constriction across the Slave River immediately downstream from the Slave-Peace-Rochers confluence is illustrated in Figure F-5. This structure raises the Slave River stages, both during high and during low river discharges, but to a much greater extent during high river flows. These high stages result in increased inflows to Lake Athabasca from the Peace River and combined with reduced outflows from the lake produce higher lake stages. Peak lake levels for the years prior to regulation (1960 to 1967) vary from 1/2 foot lower to 1-1/2 feet higher than for the natural conditions and are appreciably higher than the regulated, no-structure condition during the transition years from 1968 to 1971. Peak lake stages for the years 1960 to 1971 with the Slave River constriction and regulated Peace River flows vary from El.688.8 feet to El.692.5 feet, except during 1970 when the peak was only 685.6 feet. This low peak stage in 1970, despite the effect of the constriction , is indicative of a below average runoff period.

Although the peak lake levels are increased to natural or slightly above natural conditions by the Slave River constriction, low water stages are also increased by up to 3 feet. Minimum lake stages with the constriction vary from El.683.4 feet to El.687.1 feet. If lower minimum levels are required additional discharge capacity through the constriction is

necessary, and if similar peak lake stages are to be maintained this additional capacity must be gated.

Slave River - Alternative 1B
Gated Concrete Structure with Navigation Lock and Fish Facility

The general arrangement and details of this alternative are shown on Figure F-6.

Specifically this alternative calls for the complete closure of the waterway by a combination of rockfill and concrete gated control structures with provision for navigation and fish passage. The spillway consists of 10 openings each controlled by a 50 foot wide by 27 foot high radial gate. A concrete decking is provided across the top of the gate piers.

The navigation lock is located near the east bank. Concrete gravity walls are proposed for the lock chamber taking advantage of the rock foundation which also forms the chamber floor. The gate bay arrangement is similar to those proposed for Alternative 1A. A concrete guide wall extends upstream from the riverside lock wall also forming part of the fishway. The specific requirement for fish facilities is not yet known, hence the fishway provided is based on arbitrary assumptions.

The estimated capital cost of this alternative is $20,900,000 and details of the estimate are presented on Table F-4.

Slave River - Gated Structure - Simulated Lake Levels

Lake stages were simulated for the condition of regulated Peace River flows with the control structure gates fully open for the entire simulation period. The resulting lake hydrograph is presented as Figure F-7.

The simulated peak lake stages are up to 5-1/2 feet higher than for the natural, unregulated condition with no structure, and are up to 4 feet higher than levels simulated with the Slave River constriction. Peak lake stages range from a high of El.696.0 feet in 1965 to a low of El.689.8 feet in 1970. It should be noted that although stages of El.695.0 feet or higher are simulated by the computer model, stages of this magnitude exceed the reliable simulation limits of the model and in fact are virtually impossible in nature since the entire delta area and the Peace-Slave river valley would be inundated. No provision was made for this situation in the computer model logic.

Winter lake stages as shown on the simulated lake hydrograph are also correspondingly high and range from El.687.4 feet to El.690.7 feet.

Clearly, the discharge capacity of the structure as envisaged is insufficient since even with the gates fully opened such high lake stages result. This indicates the need for non-gated discharge capacity in conjunction with the gated control rather than additional gated area. A combination of gated control together with a rockfill weir or constriction would provide adequately high peak lake stages, and also permit

sufficiently low minimum lake stages with a degree of flexibility of both peak and minimum, within the limitations of the gated area of the control.

Riviere des Rochers - Alternative 2A
Rockfill Constriction

The general arrangement and details of the alternative are shown on Figure F-8. Basically this alternative is almost identical to the notched weir which provides a partial river closure as suggested in the report by the Alberta Water Resources Division.

The cross-section of the dump rockfill structure has been modified to be consistent with the suggested construction methods.

The axis of the structure has also been shifted slightly to minimize the quantity of rockfill. The estimated capital cost of this alternative is $950,000 and details of the estimate are presented in Table F-5.

Riviere des Rochers - Rockfill Constriction - Simulated Lake Levels

A constriction across the Rochers channel provides a direct restriction to outflow from Lake Athabasca and, unlike the control on the Slave River, the effectiveness of the scheme depends mainly on the inflow to the Lake from the surrounding catchment, rather than on the Peace-Slave river discharges. The simulated lake hydrograph for Rochers constriction and regulated Peace River flows is shown on Figure F-9.

Peak lake stages are similar to, but generally slightly lower than those achieved by the Slave River constriction, except for the 1965 peak which

is 1 foot lower and the 1970 peak which is 2 feet higher than the corresponding peaks for the Slave constriction simulation. The higher 1970 peak indicates that the below average runoff period previously noted for this year affected the Peace River flows more severely than the direct inflows to Lake Athabasca. The Rochers structure was therefore more effective in increasing the peak lake level than the Slave River constriction during this year. Peak lake levels for the 12 year period with the Rochers constriction vary from El.687.7 feet to El.691.4 feet.

The major difference between the Rochers and Slave constrictions as far as Lake Athabasca levels are concerned lies in the yearly recession limb of the lake hydrograph. With the Rochers constriction high lake stages are maintained for a longer period each year and the recession to low winter levels is much more gradual. Minimum lake stages are from 1/2 foot to 1 foot higher than is the case with the Slave constriction. If lower winter lake stages are required with the indicated peak lake levels still maintained, gated control must be used in combination with the constriction. Minimum lake levels range from El.684.6 to El.687.0 feet except during 1960 which is not considered representative because the lake elevation imposed to initiate the simulation sequence was set at El.683.7.

Riviere des Rochers - Alternative 2B
<u>Rockfill Weir</u>

The general arrangement and detail of this alternative are shown on Figure F-10.

This alternative is essentially the same as the submerged rock weir across the entire river channel as suggested in the report by the Alberta Water Resources Division.

The cross-section of the rockfill is based on the stable shape of rockfill dumped into the flowing river from a barge or aerial cableway. A special temporary fill or cribbing will be required for some end tipping of submerged fill.

The estimated capital cost of this alternative is $390,000 and details of the estimate are presented in Table F-6.

Riviere des Rochers - Rockfill Weir - Simulated Lake Levels

The proposed structure is located at the same site on the Riviere des Rochers as the rockfill constriction and has a similar effect on the lake levels. The simulated lake hydrograph for the condition of regulated Peace River flow is presented in Figure F-11.

The hydrograph demonstrates the same general characteristics as those depicted by the Rochers constriction, except that lake levels are generally from 1/2 to 1 foot lower in the case of the rockfill weir. Peak lake levels vary from El.687.4 to El.690.4 feet and minimum lake levels from El.684.0 to El.687.0 feet. The same general comments on the hydraulic effectiveness which were made for the Rochers constriction also apply to this structure. If higher peak lake stages are required either a shorter weir crest length or a higher crest elevation, or both, would be required. This, however, would also result in higher winter lake levels.

Riviere des Rochers - Alternative 2C
Gated Concrete Structure and Rockfill Dam

The general arrangement of structures and the typical sections for this alternative are shown in Figure F-12. In addition to the concrete gated structure a rockfill dam is provided to close off the remaining portion of the river channel cross-section. The spillway is designed to discharge about 62,000 cfs at a forebay level of El.690.0 feet, controlled by six-50 foot wide by 22 foot high radial gates. Consideration has also been given to the condition of reverse flow when designing the structures.

The estimated capital cost of this alternative is $5,500,000 and details of the estimate are presented on Table F-7.

Riviere des Rochers - Gated Structure - Simulated Lake Levels

This structure is located at the same site as both the rockfill weir and the rockfill constriction. The lake stages, as simulated with Option #1 of the model, are almost identical to those resulting from the simulation with the Rochers constriction for the condition of regulated Peace River flow and control gates fully open. The simulated lake hydrograph is illustrated on Figure F-13 which includes simulation runs using both Option #1 and Option #2 of the model.

Lake stages simulated with Option #2 are from 1/2 to 1 foot lower than those simulated with Option #1. Although the two options yielded very similar results during the calibration runs, the higher lake stages imposed by the Rochers control structure increases discharge through the

Revillon Coupe and this change can only be accounted for by using Option #2 where the Revillon Coupe channel is treated as an individual segment of the network. Thus, all lake stages simulated using Option #1 with control on the Rochers will be somewhat too high depending on the degree of control and the resulting extent of the increase in lake stages. This is clearly demonstrated by the results of the simulation of lake levels using both options for the case when the control gates are closed for a given period each year. As shown on Figure F-14, when the control gates are closed from May 26 to August 13 each year the levels simulated by Option #2 are from 1 to 1-1/2 feet lower than those simulated by Option #1.

Closure of the control gates for the selected time period results in an increase in peak lake levels of from 4 to 5 feet with minimum lake levels also increased by from 1 to 1-1/2 feet. These two conditions, gates fully open and gates closed from May 26 to August 13, demonstrate the degree of control and flexibility of lake levels which could be achieved by a gated control structure on the Rochers. Any desired lake stage between the limits imposed by these two conditions could be obtained by shortening the time period of gate closure. Similarily, higher lake stages, if desired in any one year, would be obtained by lengthening the closure period. An important consideration in respect to the higher lake stages however, is the tendency for the peak lake stages to occur later in the summer than they would under natural conditions. This situation is more pronounced the higher the lake stages become, and is more apparent with control on the Riviere des Rochers than with the Slave River control.

Winter lake levels with the gated control structure are considerably higher than those under natural conditions, and if lower winter levels are desired greater discharge capacity is necessary. As with the Slave River control, a combination of gated and non-gated control would provide the most effective regulation. The non-gated control must be sufficiently constricted to yield desired peak lake stages and combined with sufficient gated area to provide adequate discharge capacity to achieve the desired winter lake stages and to provide a sufficient degree of control flexibility.

ROCKFILL CONSTRUCTION METHODS

General

A considerable amount of analytical and experimental work has been done on various problems relating to the construction of rockfill dams in flowing water or to rockfill dams subject to passage of water through and over the structures, with the major efforts concentrated on the consideration of rockfill cofferdams for the purpose of river diversion during the construction period.

When rockfill dams are constructed in flowing rivers two major methods are normally used: firstly by tipping from barges (or aerial cableways) to raise the level of the dam equally across the whole length of the structure (the barge-dump method), and secondly by tipping from each bank to the full height of the dam, gradually pushing the two arms to meet each other (the toe-dump or end-tip method).

Barge Dumping

There are four distinct phases evolved in the process of dumping as defined by the cross-section profiles progressively adopted by the dumped material. Refer to Figure F-15.

Phase 1

During this phase the dumped rockfill has a triangular cross-section as shown on Figure F-15(a) and the only difference between this shape and that obtained by dumping rockfill into still water is the displacement downstream relative to the line of dumping. As the dumping continues the upstream level rises with a consequent increase in the hydraulic drop across the dumped rockfill, and the velocity of flow over the structure increases. When the velocity reaches a certain critical value the freshly dropped portion of the rockfill begins to roll down the downstream slope thus marking the end of the Phase 1.

Phase 2

During this phase dumping of rockfill results not in an increase in height of the fill, but in its elongation and the shape of the rockfill changes into a trapezoidal one as shown on Figure F-15(b). This phase continues until the mean flow velocity reaches a value which causes the rockfill to be carried downstream.

Phase 3

During this phase any increase in height will also increase the velocity resulting in newly deposited rockfill being entrained by the flowing water and carried downstream to form a flat downstream slope. Hence continuous dumping of rockfill results in both elongation and elevation of the structure as shown on Figure F-15(c).

Phase 4

This phase may be considered to begin when the elongation of the structure ceases and any further dumping of rockfill results in an increase in height without any increase in length. A cross-section approaching triangular shape builds up on the structure formed at the end of Phase 3 as shown on Figure F-15(d).

Many cofferdams have been successfully constructed in flowing water by dumping rockfill from barge or cableway with little difficulty or wastage and the method of construction whould be suitable for both the overburden and rock foundations present at Site 1 and Site 2.

For river beds with shallow overburden the construction of the dam can be arranged to make the maximum use of natural river flow to scour the loose bed material from the foundation area of the rockfill.

Where the depth of alluvium is great an initial blanket of smaller size rockfill can be deposited over the area of the foundation and for some distance downstream, to ensure that deep scour does not occur in the

river bed downstream due to the increased velocity of river flow during construction.

End Tipping

A considerable number of cofferdams have been built by the method of tipping loose material into flowing water. In general, as the dumped rock arms extend into the river channel from both banks the gap narrows and the flow velocity through the gap increases accompanied by a decrease in the discharge. Experience has shown that, with simple end-tip construction, erosion begins at the upstream corners of the gap and then spreads rapidly along the face of the gap. However, by angling the side walls of the gap to form a nozzle-type configuration as shown on Figure F-15(e) a stable condition of the dumped material can be achieved earlier and the gap then closed with smaller size rocks than would be necessary for a straight line closure.

The end-tip method is simple and therefore more widely used. But this method is limited to sites at which the river bed materials are not susceptible to erosion. If alluvial materials are present the velocity of the current could increase to erosive force during closure, not only washing away the overburden and thereby requiring additional rockfill quantities but also endangering the constantly exposed base of the rockfill structure during construction, and making closure with individual large rock very difficult.

Rockfill Structures at Site 1 on Slave River

The required rockfill structures for Alternative 1A and Alternative 1B are identical except for their required crest lengths. Since deep overburden exists near the west bank it is best to protect the overburden from erosion by a blanket of quarry-run rock which can be placed by barge with no significant increase in flow velocities. The barge can also be used to construct the lower portion of the structure which lies below the water surface. The larger sizes of rockfill can first be dumped from the barge to form the downstream toe of the structure to the maximum possible elevation. Then the quarry-run rock can be placed behind the larger size rockfill and be brought up to approximately the same elevation; the part of the structure emerging above water surface can then be constructed by the end-tip method. In order to incorporate the maximum quantity of quarry-run material in the structure this phase of construction should be raised in two stages.

In the initial stages the downstream face of the structure will be increased by end-tipping with larger size material to an elevation of a few feet above water surface level. An approach ramp can be bulldozed on the river bank for this purpose. Then quarry-run material can be tipped upstream of the larger rockfill. Finally the structure will be completed to its designed height by larger rockfill with dumped rip-rap forming the upstream face of the structures.

For rockfill structures founded on bedrock the same method of construction

could be applied except that the initial blanket of quarry-run material would not be required. Alternatively the structure may be constructed by the end-tip method only. However, this would reduce the volume of quarry-run rock which could be incorporated in the structures. Since barge dumping will be required for the western half of the structure it is proposed that the combination of barge dumping and the end-tip method be employed for the entire rockfill structure.

Rockfill Structures at Site 2 on Riviere des Rochers

The cross-section of rockfill structures for Alternative 2A and Alternative 2C is identical except for their required crest lengths. The structures can be constructed with the same methods proposed for Alternatives 1A and 1B with rock foundation. Since structures at Site 2 are subject to reverse flow, a zone of large rockfill is provided on the upstream face. If the structure is to be built by a combination of the barge-dump and end-tip methods the larger sizes of rockfill should be dumped by barge at both upstream and downstream toes. Then the quarry-run rocks can be placed by barge between the toes.

The rockfill structure for Alternative 2B is completely submerged at all times and is well suited for barge dumped construction. Moreover, the natural stable shape of the rockfill dumped in flowing water somewhat resembles the shape of structure proposed in the Athabasca Delta Project Report No. 1 prepared by the Alberta Water Resources Division.

During Phase 1 construction smaller size rockfill mixed with some

quantities of quarry-run material can be used but the average size of rockfill will need to be increased progressively in later phases. Since complete closure of the river is not required the final cross-section will be established when Phase 3 construction is reached. The cross-section of the rockfill structure shown in Figure F-10 is designed for a maximum forebay level of El.692, and since the average water level at the site during construction is estimated to be at about El.685 or lower, the natural stable cross-section as a result of dumping rockfill by barge during the construction season is expected to be somewhat shorter than the designed cross-section. Therefore, after the natural stable section has been established further dumping of rockfill will be required to extend the downstream slope to its desired length.

CAPITAL COST ESTIMATES

Estimated capital costs of the five hydraulic control structures presented have been presented in Table F-3 through Table F-7.

The unit prices for rockfill include drilling, blasting, hauling and placing and also cover the cost of labour, equipment, barges if applicable, camp facilities and transportation. The cost of providing a haul road from the quarry to the river banks is also included in the unit price. It has been assumed that no permanent access road is required.

The cost of radial gates includes hoisting equipment, stoplogs, embedded metalwork and pre-stressed trunnion anchorage. The cost of lock gates includes operating mechanism, control valves, filling and emptying system,

bulkheads, embedded metalwork and the provision of a foot bridge and control building.

In recognition of the preliminary nature of the design, a contingency allowance of 25 percent of the direct construction cost is added to arrive at total direct costs. Indirect costs are estimated to be 10 percent of the total direct costs to cover site investigation, research, design and project management, and are added to the direct construction costs.

OPERATING PROCEDURES AND PROBLEMS

Gate Operation

The operation of the gates has been limited to a simple gate open or gate closed procedure which is sufficient for the present purposes to indicate the relative effectiveness of the schemes investigated in controlling water movement and lake levels in the delta region. It has been assumed that the control gates will be raised clear of the water prior to freeze-up and left open until after break-up. Therefore operation of the gates under freezing conditions is avoided.

Following the selection of a scheme for further study, it will be necessary to develop operating rules which will provide for the annual flooding cycle in the delta and enable lake levels to be fluctuated generally within a predetermined range to provide annual variations which the water management authority considers appropriate.

Navigation

Navigation facilities have been provided at the control structures on the Slave River.

The Northern Transportation Company Limited has indicated that all barge traffic will be able to pass from Lake Athabasca into the Chenal des Quatre Fourches and negotiate the reach of the Peace River between Quatre Fourches and Riviere des Rochers. Therefore no navigation facility has been considered for the alternative control schemes located on the Rochers.

Two alternative navigation locks have been presented for Site 1 on the Slave River, one cut into the west bank and the other following the river channel and located adjacent to the east bank. Preliminary discussions with the Northern Transportation Company Limited have indicated that both routes would probably be suitable subject to some more detailed study, but river channel improvement consisting of dredging and blasting will almost certainly be required and provision for this item in the cost estimate is presumed to be made in the contingency allowance.

Ice Movement

It is proposed that the gates would be maintained in the raised position during the freeze-up. The gate control structures would be suitably armoured for protection against moving ice and designed for the thrust of surface ice formation.

A control structure on the Slave River would probably lessen the threat of flooding by ice jams downstream and no aggravation of the situation upstream is anticipated.

ALTERNATIVE METHODS OF HYDRAULIC CONTROL

General

In addition to the uncontrolled rockfill structures and gated control structures, a number of other schemes were considered. As well as the impoundment at the Mamawi Lake outlet these comprise a temporary blockage of the Riviere des Rochers by a man-made ice dam; assisting the natural occurrence of Slave River jamming during the spring break-up; complete blockage of the Revillon Coupe with fill; a submerged rockfill weir on the Chenal des Quatre Fourches; the use of inflatable, neoprene coated fabric dams (Fabridam); and advance construction of the diversion dam, spillway and power intake for a proposed hydro power development downstream at Mountain Rapids on the Slave River.

Existing Dam at Mamawi Lake Outlet

A temporary rockfill dam was constructed during the winter of 1971-1972 on the branch of the Chenal des Quatre Fourches which controls the flow between Mamawi Lake and Four Forks. Initially the dam was constructed to El.684.

This action was taken as an interim measure to impound inflowing water from the Birch River and raise the levels of Lakes Claire, Mamawi, Baril

and the other numerous lakes and ponds in a region covering about 60 percent of the Delta area. The impoundment was initially effective during the spring runoff of 1972 and as the lake levels rose the dam was raised to El.688.5 from a prepared stockpile of rockfill. At the end of June the water levels in Lake Claire and Mamawi Lake had reached the top of the dam.

The scheme is intended as a short term solution until action is initiated for a long term remedial plan to provide acceptable hydraulic control of the Peace-Athabasca Delta region and Lake Athabasca. Full details on this impoundment structure are given in Section L.

Ice Dams and Jamming

a) Ice Dam on Riviere des Rochers

The concept of installing a temporary ice dam on the Riviere des Rochers was studied with the object of completely blocking this channel during the 6-month period from January to June. The average inflow for the 6-month period is approximately 19,000,000 acre-feet. This would represent a gross increase in the level of Lake Athabasca of about 5-1/2 feet which would be reduced by about 20 percent due to the outflow through the Chenal des Quatre Fourches.

The most suitable location for the ice dam is at Site 2 on Riviere des Rochers.

The feasibility of the scheme depends on establishing a complete

blockage of the channel using a network of cryopiles, and by upstream blasting of ice to create an ice mass in the channel. The feasibility also depends on being able to maintain the ice dam in a stable condition during the spring. The details of the ice dam investigations are given in Section G.

b) Ice Jamming on the Slave River

Ice jamming on the Slave River has historically been a contributing factor to the inundation of the Peace-Athabasca Delta region during the spring break-up. Jamming occurred during the 1972 spring break-up and materially assisted in the substantial flooding of the Delta region.

It might therefore be possible to assist the formation of ice jams at an appropriate location on the Slave River by the use of massive concrete anchor blocks on opposite banks to support floated steel cables which would induce blockage of ice.

Blockage of Revillon Coupe

A possible method of obtaining a modest increase in the level of Lake Athabasca would be to provide complete blockage of the Revillon Coupe. An approximate measure of the increase in the lake level is given in Figure F-13, which compares the hydrographs for regulated Peace River flows, firstly using the computer model Option #1, which does not consider the Revillon Coupe, and secondly using Option #2, which provides

a solution including the Revillon Coupe. It can be seen that the level is about one foot higher when the Revillon Coupe is ignored. This is not an accurate representation and would tend to be greater for high lake stages and less for low lake stages.

However, following a preliminary review of the possible cost of blocking the Revillon Coupe versus effectiveness in providing lake level control, the method was rejected.

Submerged Weir on Chenal des Quatre Fourches

A detailed study of a control structure on the Chenal des Quatre Fourches has not been made since in the limited time available the effort has been concentrated at the more promising sites. The reasons for this are:

a) only about 20 percent of the lake outflow is carried by this channel;

b) it provides the main navigation route between the lake and the Peace River;

c) it is probably the main channel for the movement of fish;

d) complete control of the Delta region cannot be achieved.

The changes in velocities in the Chenal des Quatre Fourches, due to control structures on the Riviere des Rochers have been investigated and generally indicate that velocities may increase from the order of two feet per second to about three per second. In addition, during low stages of the Peace River, critical flow conditions may develop at the downstream

end of the connecting channels. Further investigation of these two factors may indicate the advisability of a submerged weir near the downstream end of the Chenal des Quatre Fourches (at or near Site 4) to prevent progression of channel erosion upstream from the Peace River. However, it would be necessary to establish that such a weir would not interfere with navigation or the movement of fish.

Inflatable Dam Control - Fabridam

The possibility of using inflatable neoprene coated fabric dams (Fabridam) at the proposed hydraulic controls at Site 1, and Site 2 was considered. The use of the Fabridam was also considered for controlling the navigation lock required for the Slave River scheme. Following an exchange of correspondence and a meeting with the manufacturer, it was concluded that the use of Fabridam for this purpose could not be recommended at the present time.

In the case of the use of Fabridam as a control gate the limiting height of about 12 feet is a severe restriction and, in addition, the extremely low temperatures and the possibility of heavy ice flows passing through the control could cause extensive damage to the Fabridam installation. Further, a Fabridam installation should only be used if a sudden release of the impoundment in the event of failure would be acceptable. In the case of a hydraulic control gate for Lake Athabasca storage, this would not be acceptable. Again, when considering Fabridam as a means of controlling the navigation lock, it was established that the height

required exceeds the recommended height of about 12 feet stipulated by the manufacturer.

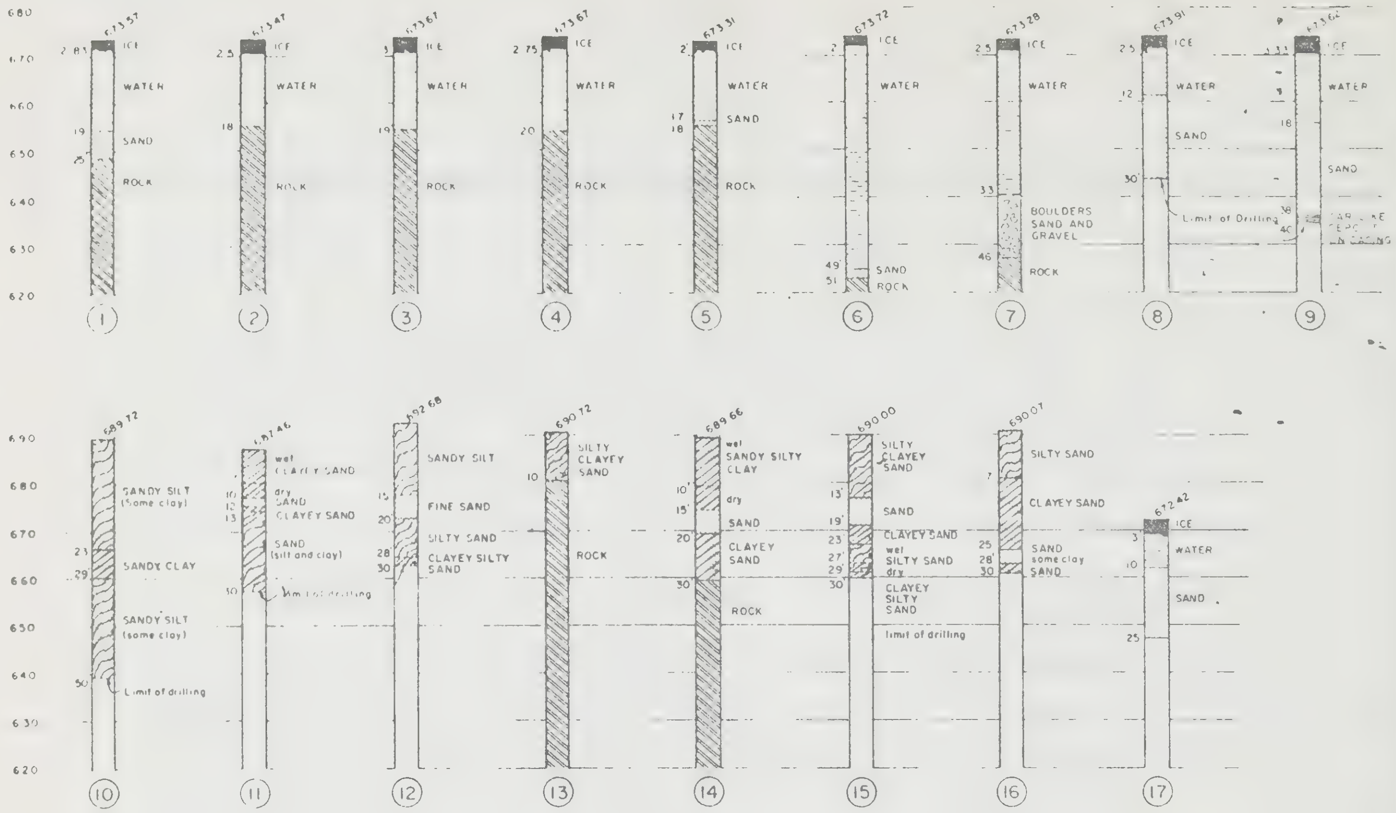
Generally, the manufacturers do not yet have the experience to guarantee the capability of the Fabridam assembly to remain operational under the expected extreme low temperatures, or under the effect of the massive ice flows which are anticipated. It is possible that an unprogrammed release, or an inability to reconstitute closure, could occur with a Fabridam due to failure of the inflation system input, or major damage to the assembly sufficient to overbalance input capacity, and for this reason the Fabridam installation would be unacceptable as a solution.

Power Development on the Slave River

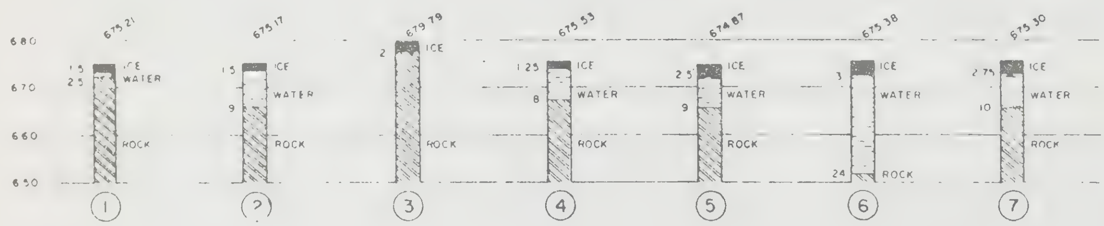
Preliminary studies of a hydro power development at Mountain Rapids on the Slave River have been carried out on behalf of Calgary Power Limited, and it appears that a dam and spillway could be built at that location which would provide a fluctuation of levels in the Peace-Athabasca Delta region within the range which has been generally proposed as being ecologically desirable. Further review of this alternative should be undertaken to establish if the development of hydro power could be compatible with the ecological requirements. It appears that the hydro development dam could be designed with suitable operating and surcharge levels such that the river levels near the confluence of the Peace and Slave Rivers could be fluctuated through the desired range to simulate the short term inundation of the Peace-Athabasca Delta region during the spring. This study might disclose an economic justification for

building the dam, spillway, and if necessary, the power intake, in advance of the power facilities.

F34



SITE No. 1
SLAVE RIVER DRILL HOLE LOGS



SITE No. 2
RIVIERE DES ROCHERS DRILL HOLE LOGS

PEACE - ATHABASCA DELTA PROJEC	
ALBERTA WATER RESOURCES DIVISION	
SLAVE RIVER - SITE No 1 RIVIERE DES ROCHERS - SITE No. 2 DRILL HOLE LOGS	
GEPAC STANLEY & ASSOCIATES LTD	
DATE JUNE 1972	Table F-1

TABLE F-2
Sheet 1 of 2

SLAVE RIVER - SITE NO. 1 & RIVIERE DES ROCHERS - SITE NO. 2
DRILL HOLE TEST RESULTS

	Hole Designation	Bedrock Sample Elevation	Overburden Sample Elevation	Description
SLAVE RIVER - SITE 1	S2	El. 654'		Metamorphic rock of granitic nature; mainly quartz plus various feldspars associated with quartz.
	S8		El. 659'	Sand, dark brown colour.
	S10-1		El. 670'	Sandy silt, fine brown colour with coal traces. See Table 6-3 for grain size curve.
	S10-2		El. 640'	Sandy silty clay. Low plasticity index 2.7.
RIVIERE DES ROCHERS - SITE 2	R1	El. 672'		Metamorphic granitic rock.
	R3	El. 676'		Metamorphic granitic rock, mainly feldspars, ranging from orthoclase to microcline associated with quartz. Also some individual fragments of quartz and chert.
	R5	El. 664'		Metamorphic granitic rock, predominately feldspar.

TABLE F-2
Sheet 2 of 2

SLAVE RIVER - SITE NO. 1 & RIVIERE DES ROCHERS - SITE NO. 2

DRILL HOLE TEST RESULTS

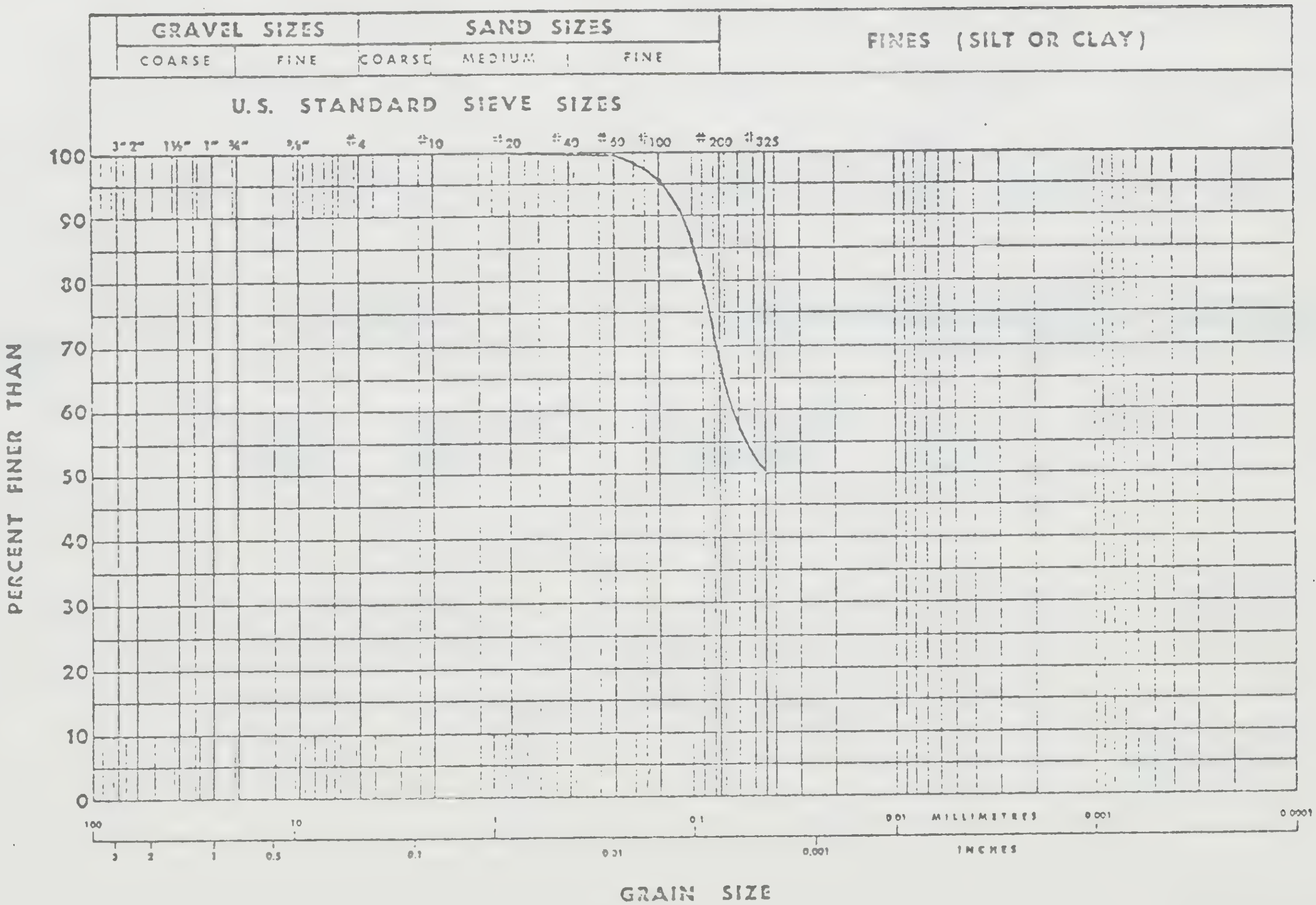


TABLE F-3

CAPITAL COST ESTIMATE

SLAVE RIVER - ALTERNATIVE 1A

Item	Description	Quantity	Unit	Unit Price	Cost
1.	Excavation in common material	139,000	cu. yd	$ 2.00	$ 278,000
2.	Cofferdam and dewatering	-	L.S.	-	580,000
3.	Placing fill (excavated) material for dykes	30,000	cu.yd.	.50	15,000
4.	Supply and placing riprap	50,000	cu.yd	12.50	625,000
5.	Supply and placing rockfill	220,000	cu.yd.	9.50	2,090,000
6.	Supply and placing mass concrete for gate structure	21,000	cu.yd.	200.00	4,200,000
7.	Supply and placing structural concrete for floor beams	1,000	cu.yd.	250.00	250,000
8.	Supply and install steel sheetpile	565	tons	1,000.00	565,000
9.	Supply and placing filter material on lock chamber floor	3,200	cu.yd.	25.00	80,000
10.	Supply and install floating guide boom	-	L.S.	-	50,000
11.	Supply and install lock gates and miscellaneous equipment	-	L.S.	-	$ 530,000
	DIRECT COST				9,263,000
	Contingency allowance (25%)				2,316,000
	TOTAL DIRECT COST				11,579,000
	Indirect cost (10%)				1,158,000
	CAPITAL COST ESTIMATE				$12,737,000

TABLE F -4

CAPITAL COST ESTIMATE
SLAVE RIVER - ALTERNATIVE 1B

Item	Description	Quantity	Unit	Unit Price	Cost
1.	Excavation in rock	1.000	cu.yd.	$ 20.00	$ 20,000
2.	Cofferdam and dewatering	-	L.S.	-	1,500,000
3.	Supply and placing rockfill	290,000	cu.yd.	11.00	3,190,000
4.	Supply and placing mass concrete for gate and lock structures	25,000	cu.yd.	200.00	5,000,000
5.	Supply and placing structural concrete for control structure and spillway	10,200	cu.yd.	250.00	2,550,000
6.	Supply and install radial gates hoists and miscellaneous metal work	-	L.S.	-	1,820,000
7.	Supply and install lock gate and miscellaneous equipment	-	L.S.	-	$ 530,000
	DIRECT COST				14,610,000
	Contingency allowance (25%)				3,652,500
	TOTAL DIRECT COST				18,262,500
	Indirect Cost (10%)				1,826,500
	CAPITAL COST ESTIMATE				$20,089,000

TABLE F-5

CAPITAL COST ESTIMATE
RIVIERE DES ROCHERS - ALTERNATIVE 2A

Item	Description	Quantity	Unit	Unit Price	Cost
1.	Supply and placing rockfill	42,000	cu.yd.	$16.50	$693,000
	DIRECT COST				693,000
	Contingency allowance (25%)				173,400
	TOTAL DIRECT COST				866,400
	Indirect Cost (10%)				86,600
	CAPITAL COST ESTIMATE				$953,000

TABLE F-6

CAPITAL COST ESTIMATE
RIVIERE DES ROCHERS - ALTERNATIVE 2B

Item	Description	Quantity	Unit	Unit Price	Cost
1.	Supply and placing rockfill	24,000	cu.yd.	$ 11.70	$280,800
	DIRECT COST				280,800
	Contingency allowance				70,200
	TOTAL DIRECT COST				351,000
	Indirect cost (10%)				35,000
	CAPITAL COST ESTIMATE				$386,000

TABLE F-7

CAPITAL COST ESTIMATE
RIVIERE DES ROCHERS- ALTERNATIVE 2C

Item	Description	Quantity	Unit	Unit Price	Cost
1.	Excavation in rock	4,400	cu.yd.	$ 20.00	$ 88,000
2.	Cofferdaming and dewatering	-	L.S.	-	700,000
3.	Supply and placing rockfill	45,000	cu.yd.	8.30	373,500
4.	Supply and placing mass concrete for gate structure	7,500	cu.yd.	200.00	1,500,000
5.	Supply and placing structural concrete for gate structure	3,000	cu.yd.	250.00	750,000
6.	Supply and install radial gates, hoists and miscellaneous metal-work	-	L.S.	-	$ 590,000
	DIRECT COST				4,001,500
	Contingency allowance (25%)				1,000,500
	TOTAL DIRECT COST				5,002,000
	Indirect cost (10%)				500,000
	CAPITAL COST ESTIMATE				$5,502,000

SCALE: 1" = 6 MILES

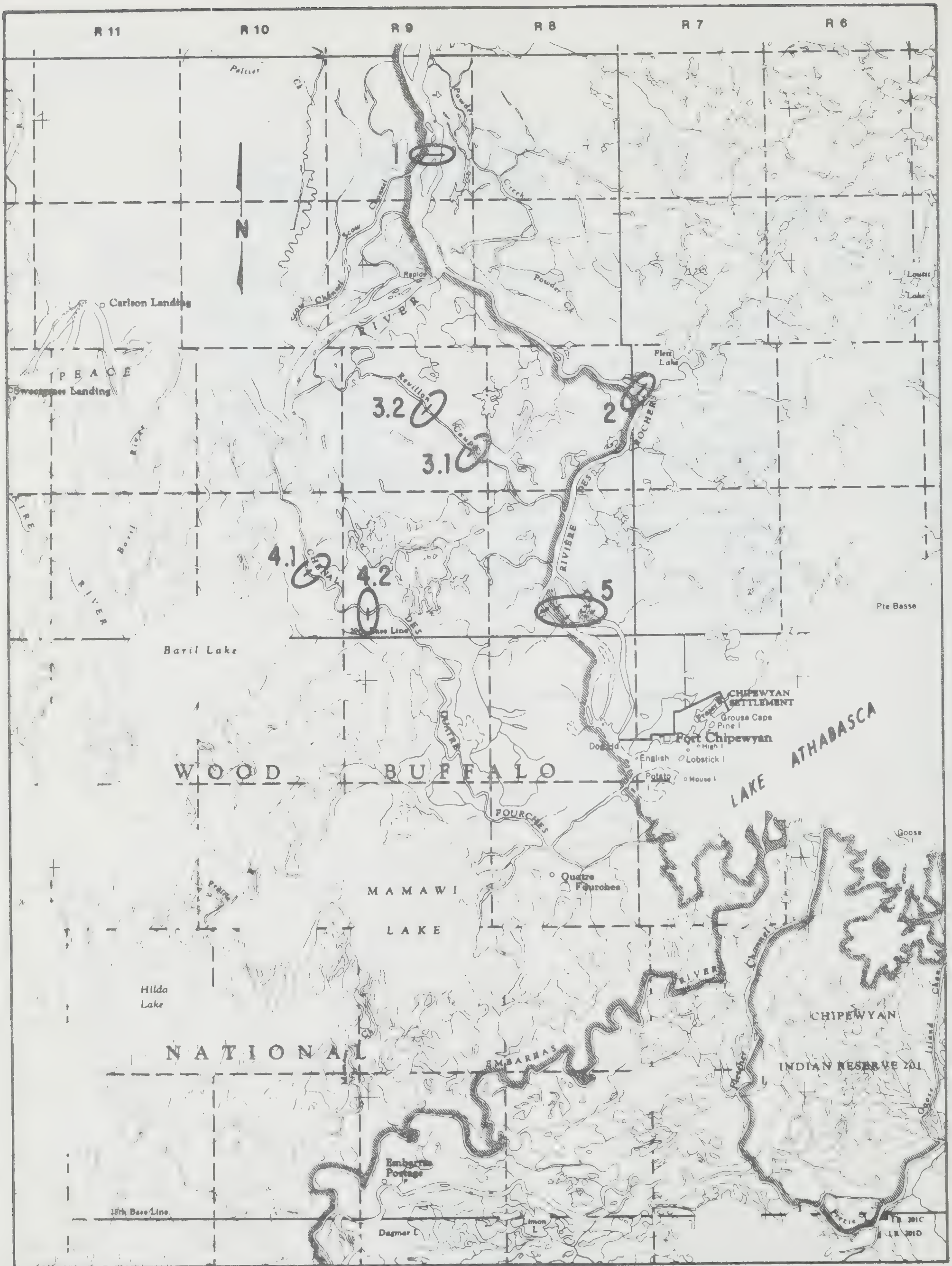
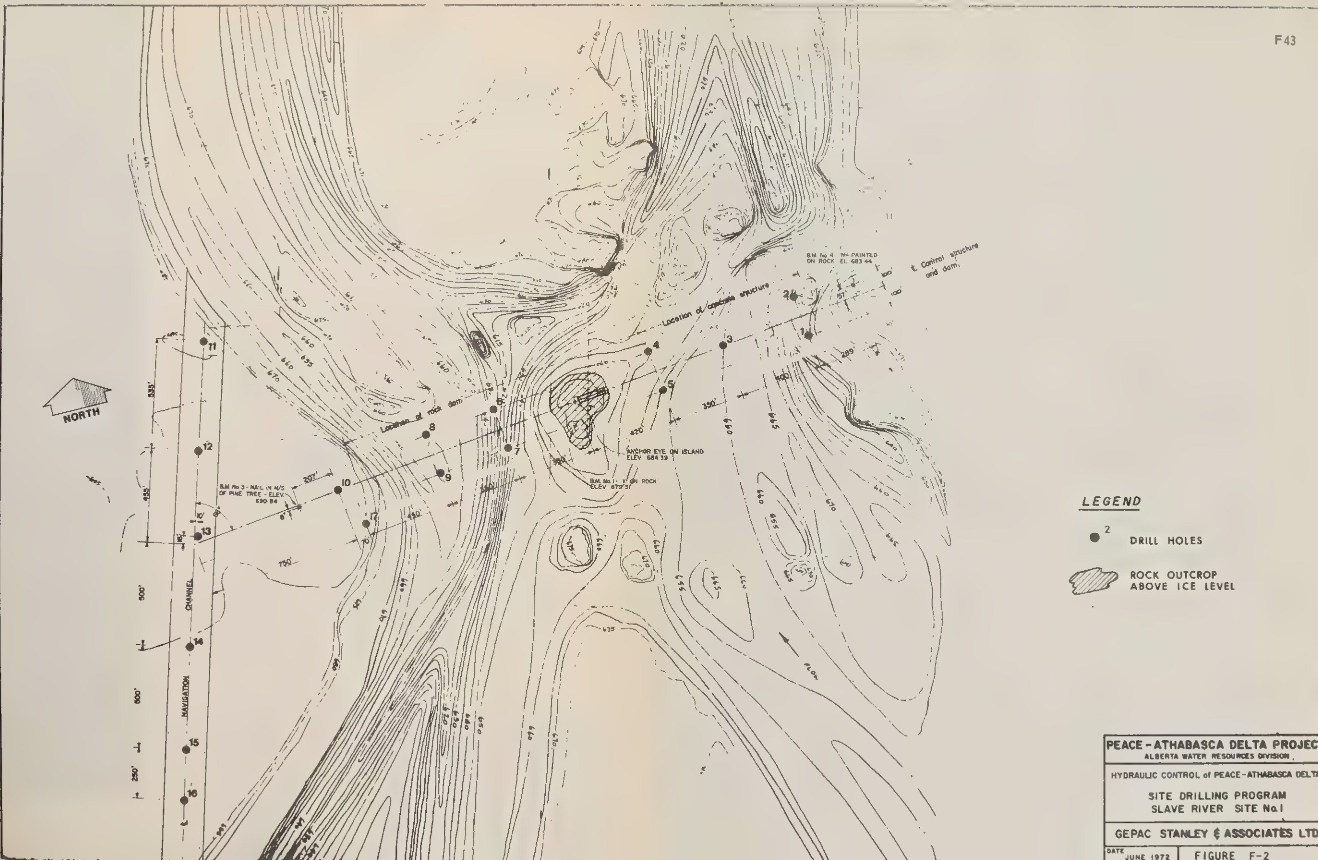
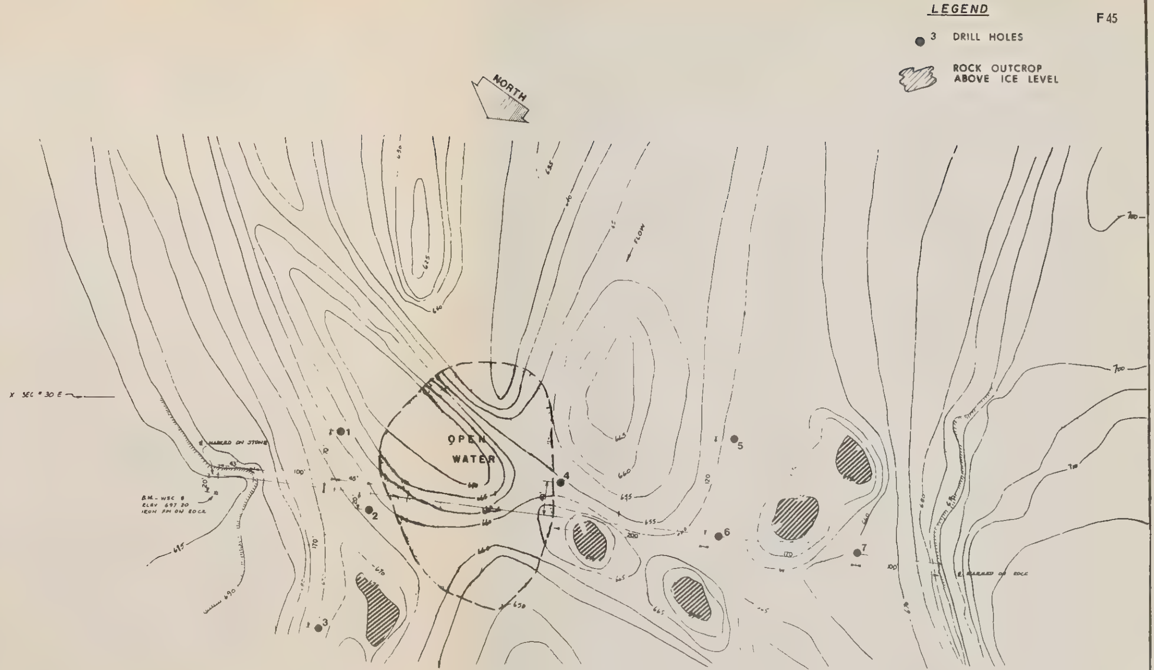


Figure F-1. Alternative Sites for Major Water Level Control Structures.



PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION
HYDRAULIC CONTROL of PEACE-ATHABASCA DELTA
SITE DRILLING PROGRAM
SLAVE RIVER SITE No. I
GEPAC STANLEY & ASSOCIATES LTD.
DATE JUNE 1972
FIGURE F-2



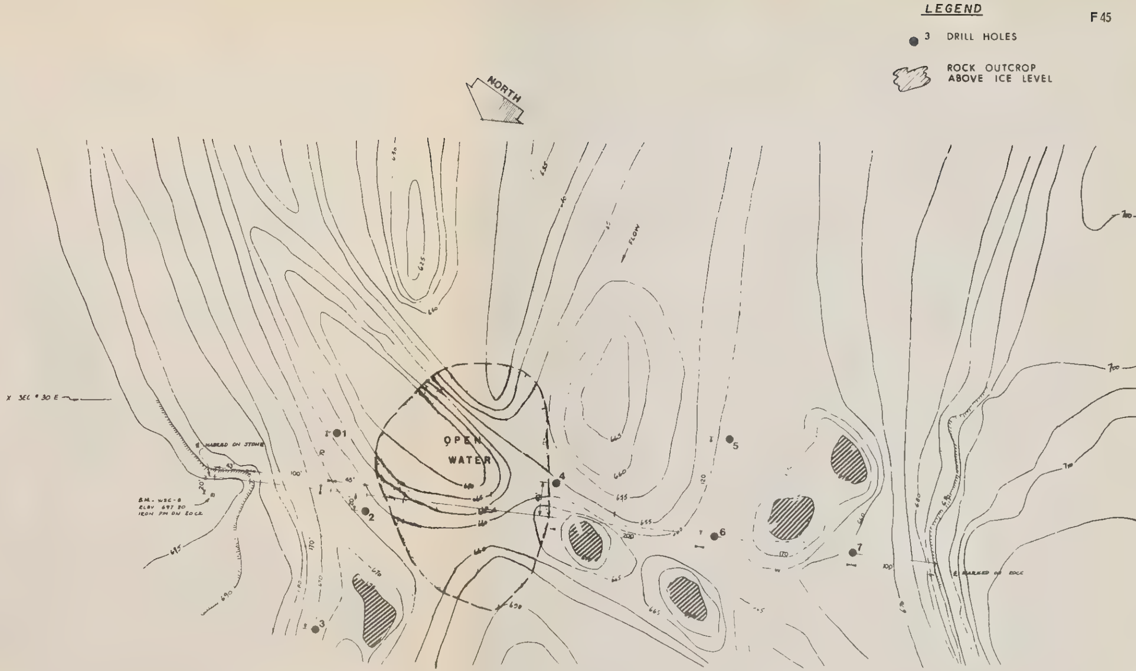
PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION

HYDRAULIC CONTROL of PEACE - ATHABASCA DELTA

SITE DRILLING PROGRAM
RIVIERE DES ROCHERS - SITE No 2

GEPAC STANLEY & ASSOCIATES LTD

DATE JUNE 1972	FIGURE F-3



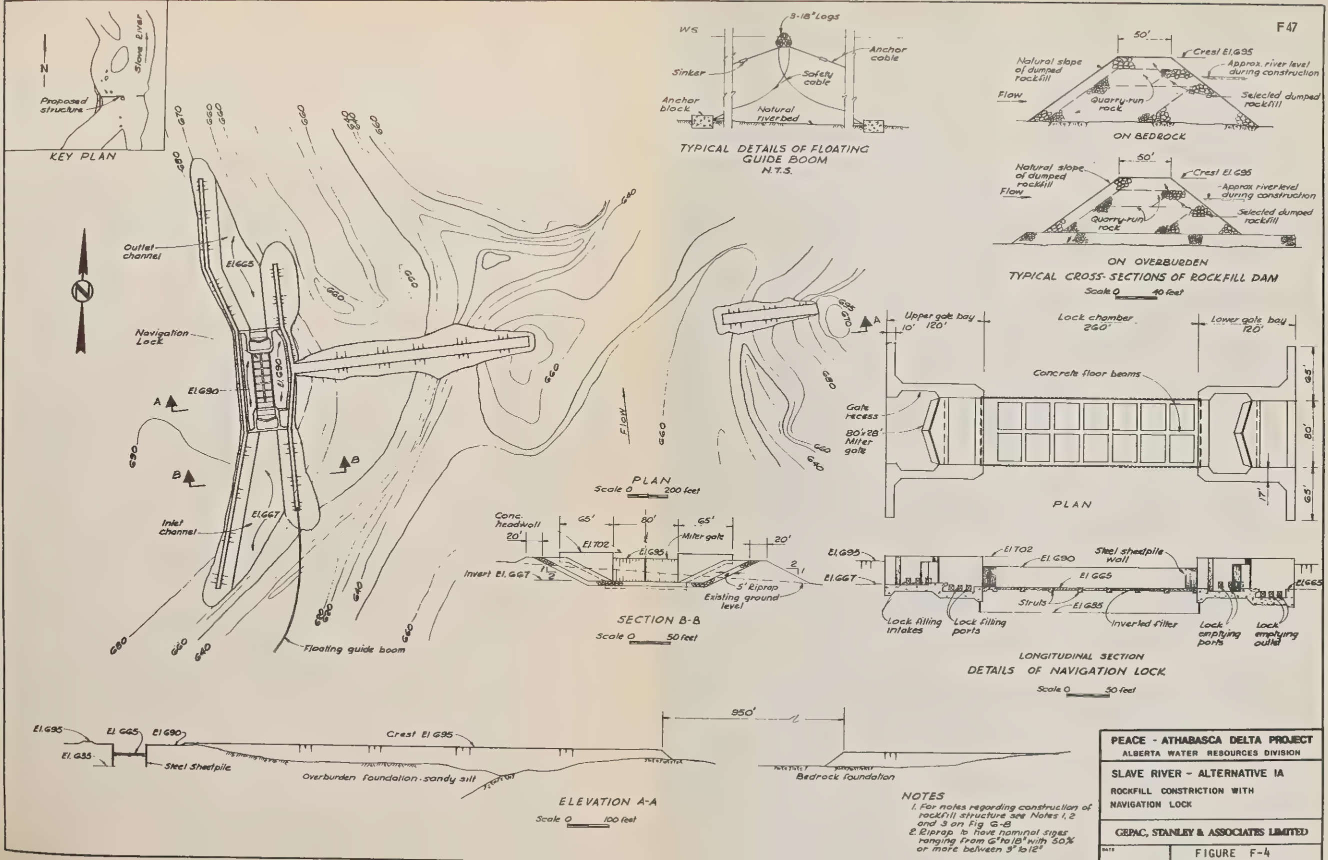
PEACE-ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION

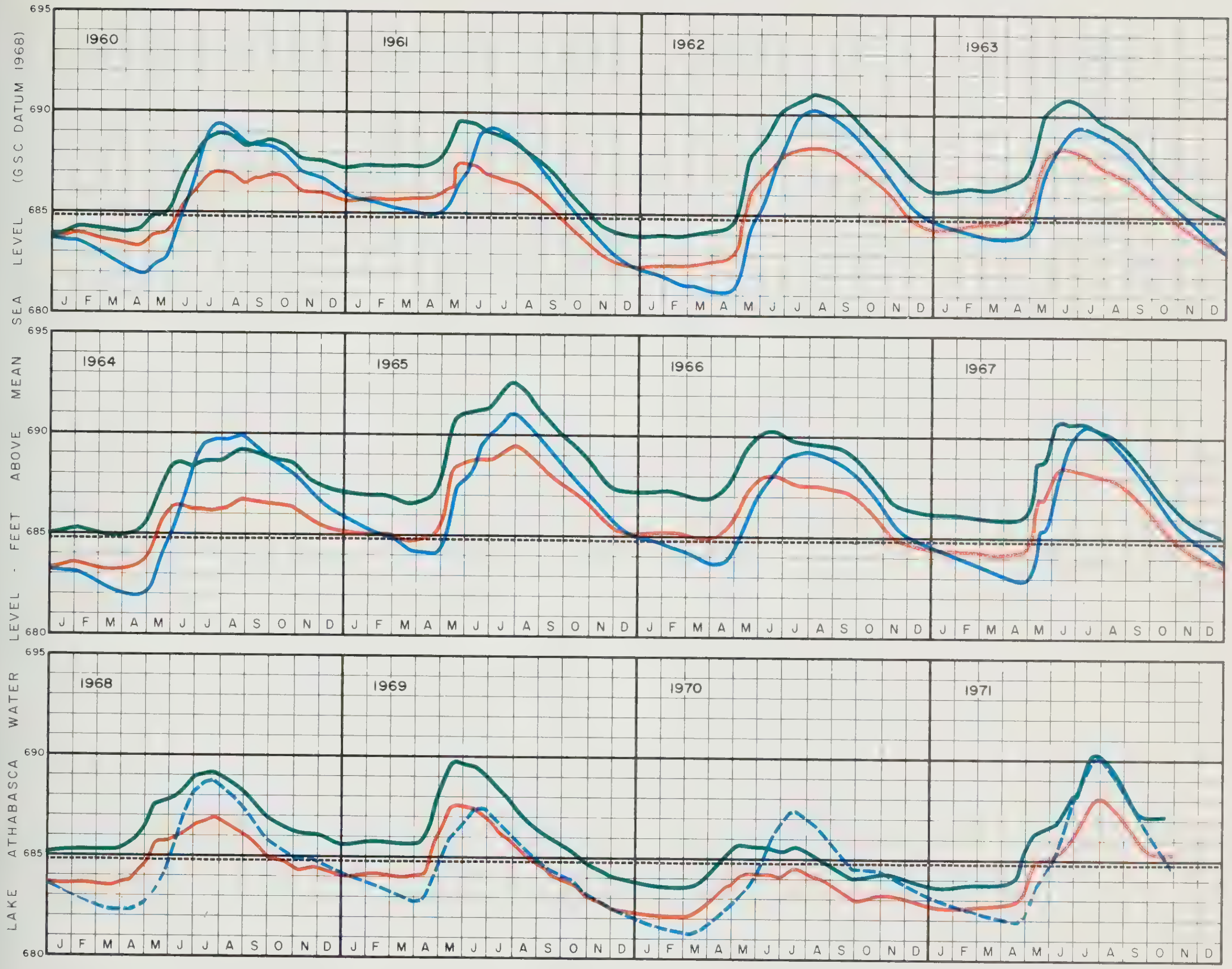
HYDRAULIC CONTROL of PEACE-ATHABASCA DELTA

SITE DRILLING PROGRAM
RIVIERE DES ROCHERS-SITE No 2

GEPAC STANLEY & ASSOCIATES LTD

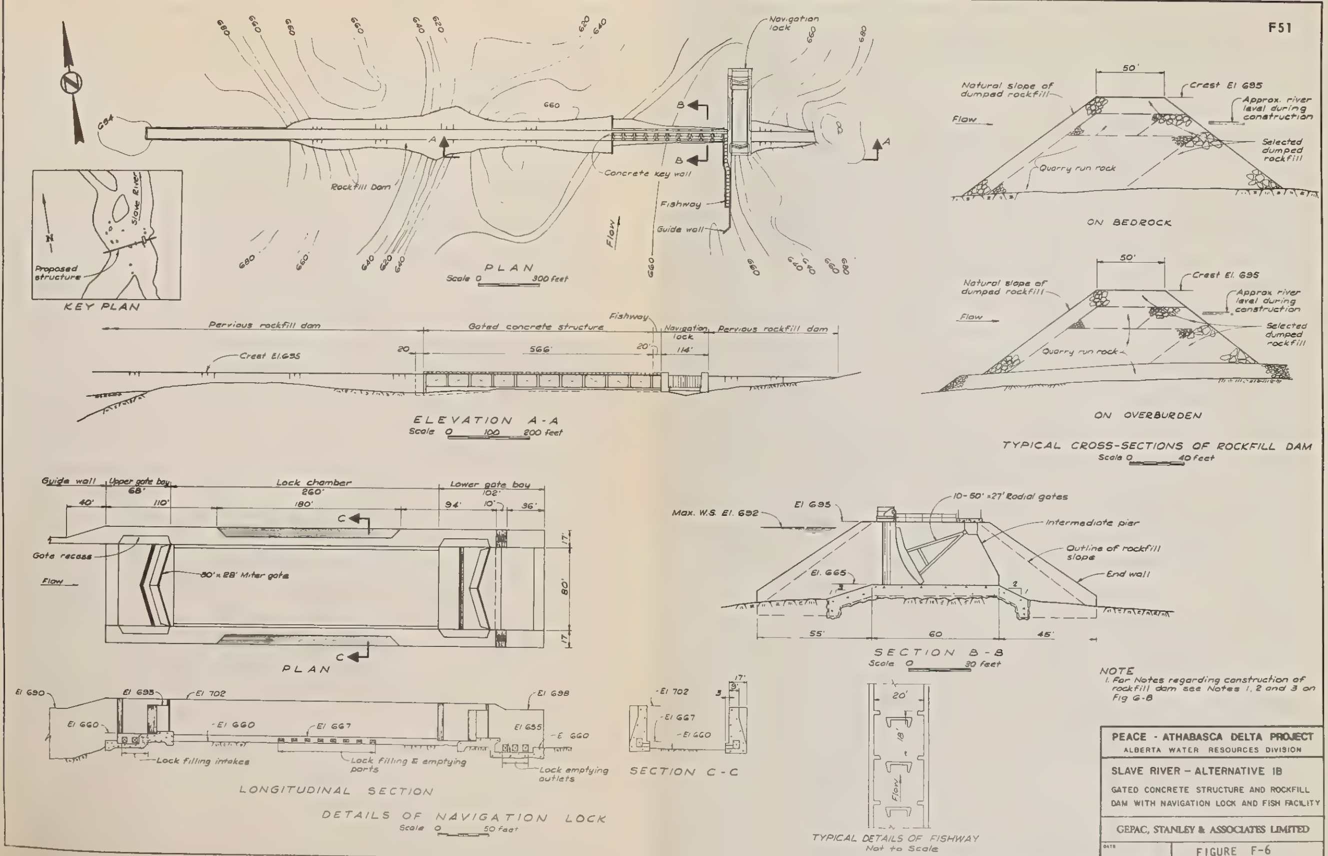
DATE JUNE 1972	FIGURE F-3


KEY PLAN
N
Slave River
Proposed structure
TYPICAL DETAILS OF FLOATING GUIDE BOOM
N.T.S.
3-18" Logs
WS
Anchor cable
Sinker
Safety cable
Anchor block
Natural riverbed
TYPICAL CROSS-SECTIONS OF ROCKFILL DAM
Scale 0 40 feet
ON BEDROCK
ON OVERBURDEN
50'
Crest El.695
Natural slope of dumped rockfill
Approx. river level during construction
Flow
Quarry-run rock
Selected dumped rockfill
PLAN
Scale 0 200 feet
Outlet channel
El.665
Navigation Lock
El.690
Inlet channel
El.667
Floating guide boom
Flow
A
B
690
680
670
660
640
695
SECTION B-B
Scale 0 50 feet
Conc. headwall
20'
65'
80'
65'
20'
El.702
El.695
Miter gate
Invert El.667
5' Riprap
Existing ground level
DETAILS OF NAVIGATION LOCK
Scale 0 50 feet
PLAN
Upper gate bay
10' 120'
Lock chamber
260'
Lower gate bay
120'
Concrete floor beams
Gate recess
80'x28' Miter gate
65'
80'
65'
17'
LONGITUDINAL SECTION
El.695
El.667
El.702
El.690
Steel sheetpile wall
El.665
El.635
Struts
Inverted filter
Lock filling intakes
Lock filling ports
Lock emptying ports
Lock emptying outlet
ELEVATION A-A
Scale 0 100 feet
El.695
El.665
El.690
El.635
Crest El.695
950'
Steel Sheetpile
Overburden foundation - sandy silt
Bedrock foundation
NOTES
1. For notes regarding construction of rockfill structure see Notes 1, 2 and 3 on Fig G-8
2. Riprap to have nominal sizes ranging from 6" to 18" with 50% or more between 9" to 12"
PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION
SLAVE RIVER - ALTERNATIVE IA
ROCKFILL CONSTRICTION WITH NAVIGATION LOCK
GEPAC, STANLEY & ASSOCIATES LIMITED
FIGURE F-4

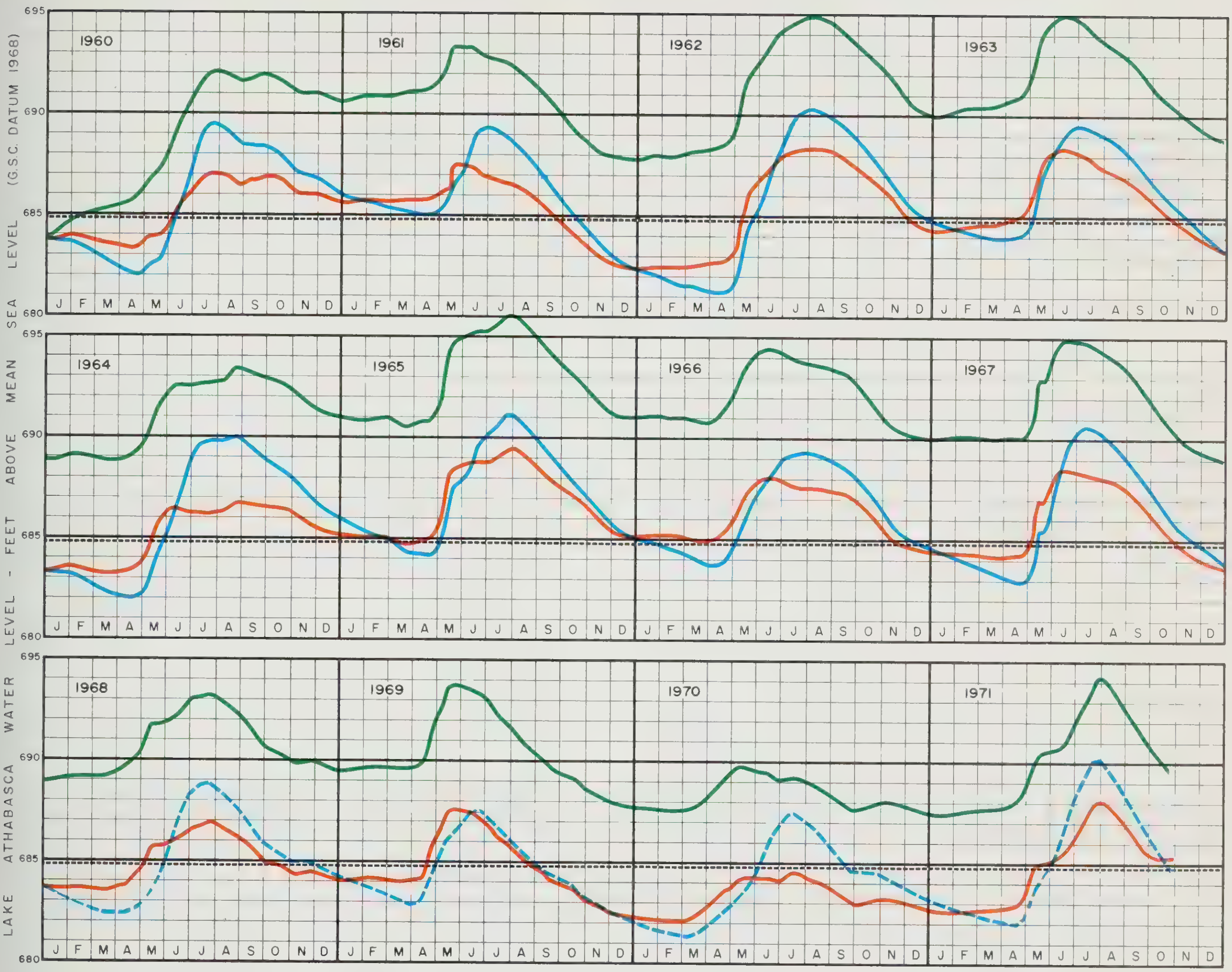


- - - - - - Approximate average annual lake level (1930 to 1970)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of the Slave River constriction

FIGURE F-5 Lake Athabasca Hydrographs, Slave River Rockfill Constriction

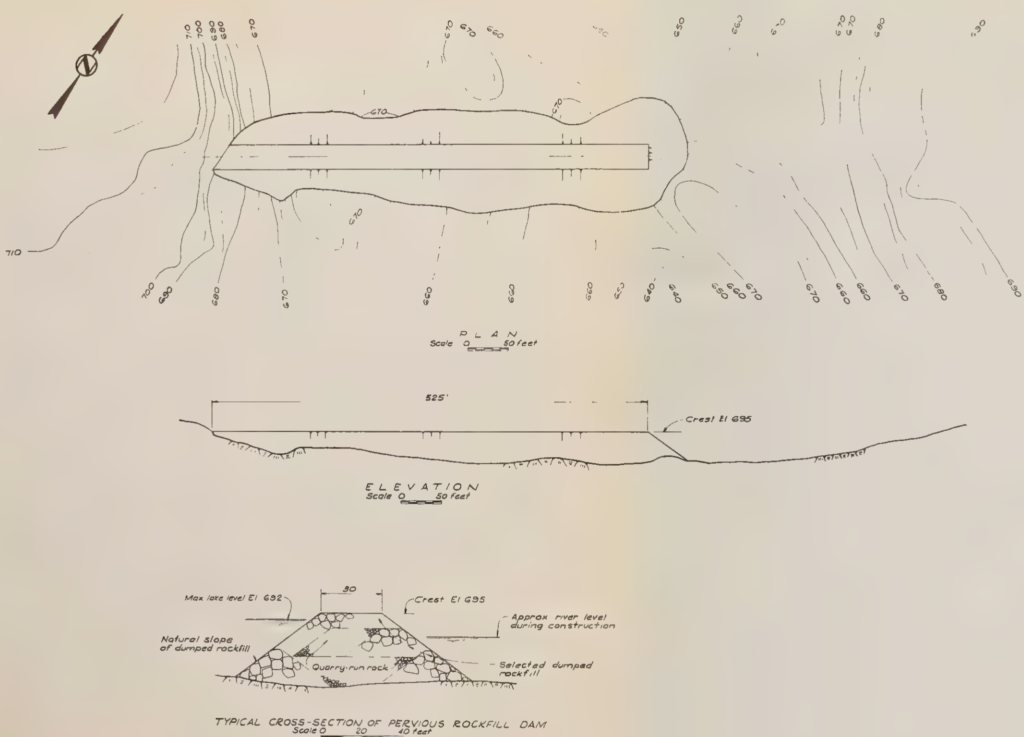


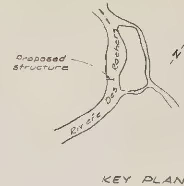
F51
Navigation lock
Concrete key wall
Fishway
Guide wall
Rockfill Dam
Flow
PLAN
Scale 0 300 feet
Slave River
N
Proposed structure
KEY PLAN
Pervious rockfill dam
Gated concrete structure
Fishway
Navigation lock
Pervious rockfill dam
20
566'
20'
114'
Crest El.695
ELEVATION A-A
Scale 0 100 200 feet
Natural slope of dumped rockfill
50'
Crest El 695
Approx. river level during construction
Flow
Selected dumped rockfill
Quarry run rock
ON BEDROCK
Natural slope of dumped rockfill
50'
Crest El. 695
Approx. river level during construction
Flow
Selected dumped rockfill
Quarry run rock
ON OVERBURDEN
TYPICAL CROSS-SECTIONS OF ROCKFILL DAM
Scale 0 40 feet
Guide wall
Upper gate bay 68'
Lock chamber 260'
Lower gate bay 102'
40'
110'
180'
94'
10'
36'
Gate recess
80'x 28' Miter gate
Flow
17'
80'
17'
PLAN
Max. W.S. El. 692
El 695
10-50'x27' Radial gates
Intermediate pier
Outline of rockfill slope
El. 665
End wall
55'
60
45'
SECTION B-B
Scale 0 30 feet
El 690
El 695
El 702
El 698
El 660
El 660
El 667
El 655
El 660
Lock filling intakes
Lock filling & emptying ports
Lock emptying outlets
LONGITUDINAL SECTION
El 702
El 667
El 660
17'
SECTION C-C
DETAILS OF NAVIGATION LOCK
Scale 0 50 feet
20'
18'
Flow
TYPICAL DETAILS OF FISHWAY
Not to Scale
NOTE
1. For Notes regarding construction of rockfill dam see Notes 1, 2 and 3 on Fig G-8
PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION
SLAVE RIVER – ALTERNATIVE 1B
GATED CONCRETE STRUCTURE AND ROCKFILL DAM WITH NAVIGATION LOCK AND FISH FACILITY
GEPAC, STANLEY & ASSOCIATES LIMITED
FIGURE F-6



-------- Approximate average annual lake level (1930-70)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of Slave River gated control structure (gates always open)

FIGURE F-7 Lake Athabasca Hydrographs, Slave River Gated Control Structure, Gates Open





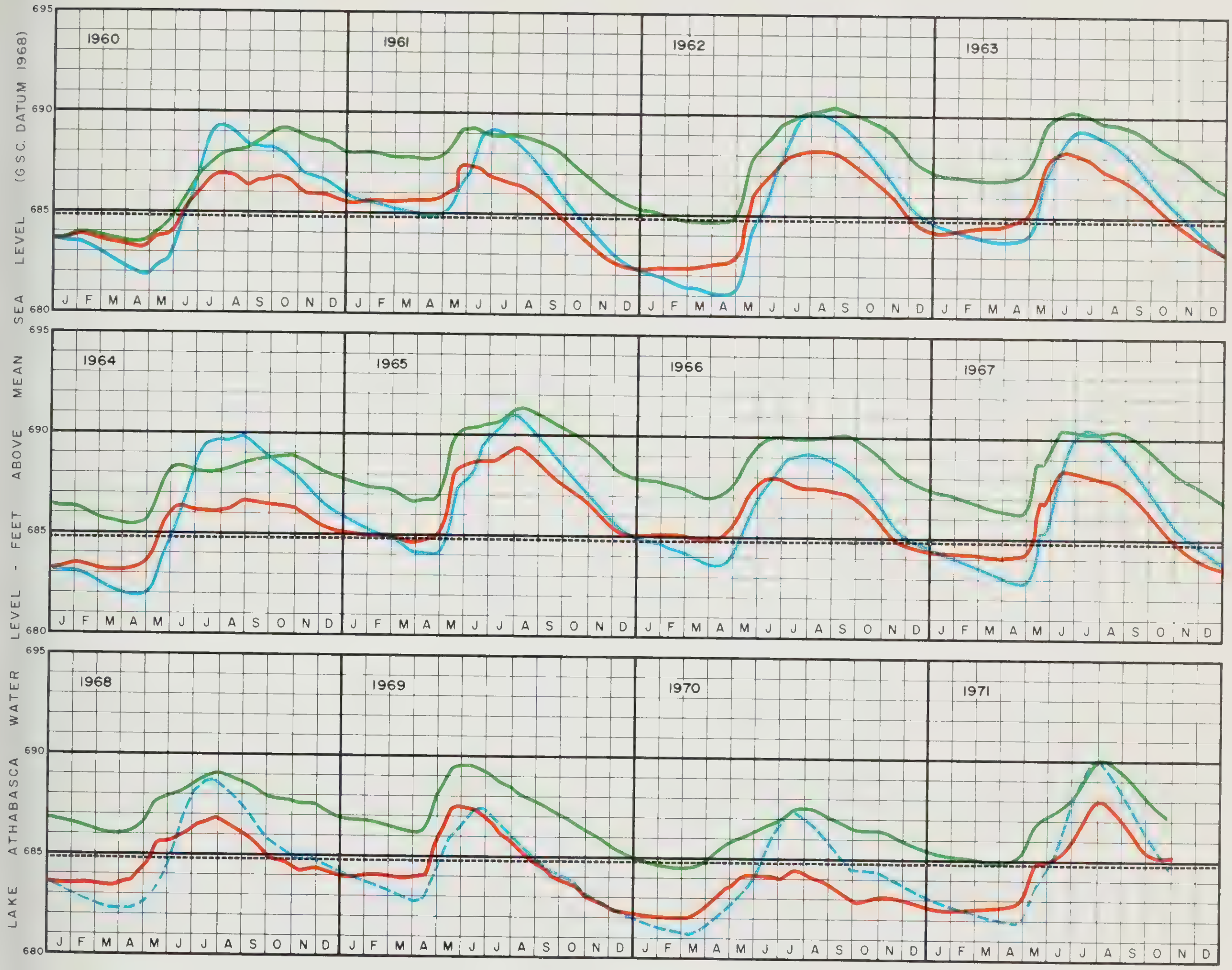
NOTES
1. Rockfill above river level during construction to be end-dumped by trucks & pushed out using earth-moving equipment
2. Rockfill below river level during construction may be barge dumped
3. Selected rockfill to have nominal sizes ranging from 12" to 48" with 50% or more between 24" to 30"

PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION

RIVIERE DES ROCHERS – ALTERNATIVE 2A
ROCKFILL CONSTRICTION

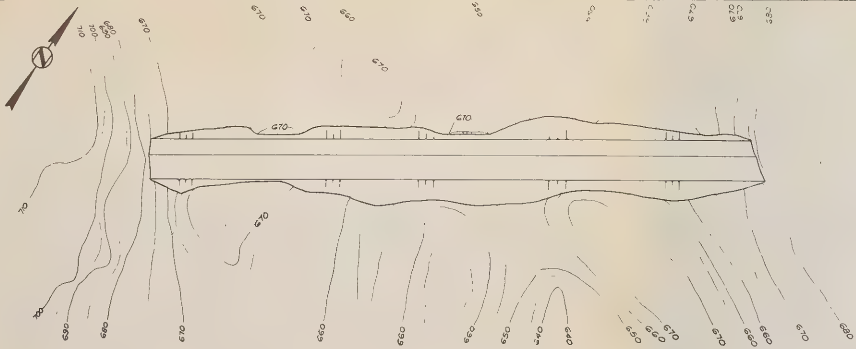
GEPAC, STANLEY & ASSOCIATES LIMITED

FIGURE F-8

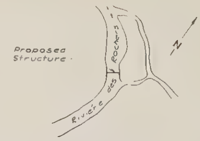


- - - - - - Approximate average annual lake level (1930-70)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of Little Rapids constriction

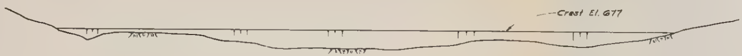
FIGURE F-9 Lake Athabasca Hydrographs, Rivière des Rochers, Little Rapids Rockfill Constriction



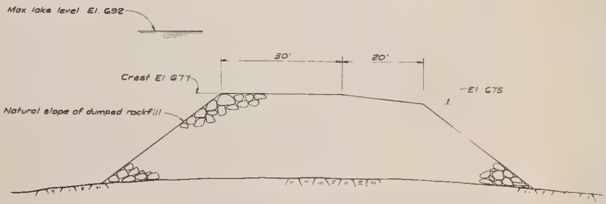
PLAN
Scale 0 50 feet



KEY PLAN



ELEVATION
Scale 0 50 feet



TYPICAL CROSS-SECTION OF PERVIOUS ROCKFILL WEIR
Scale 0 10 20 feet

NOTES

1. Rockfill to be barge-dumped or placed by aerial cableway
2. The rockfill structure to be built-up at an even rate over the full width of river cross-section
3. Bulk of the rockfill to have minimum nominal size of 15" except for the initial dumping when material smaller than 15" may be used.

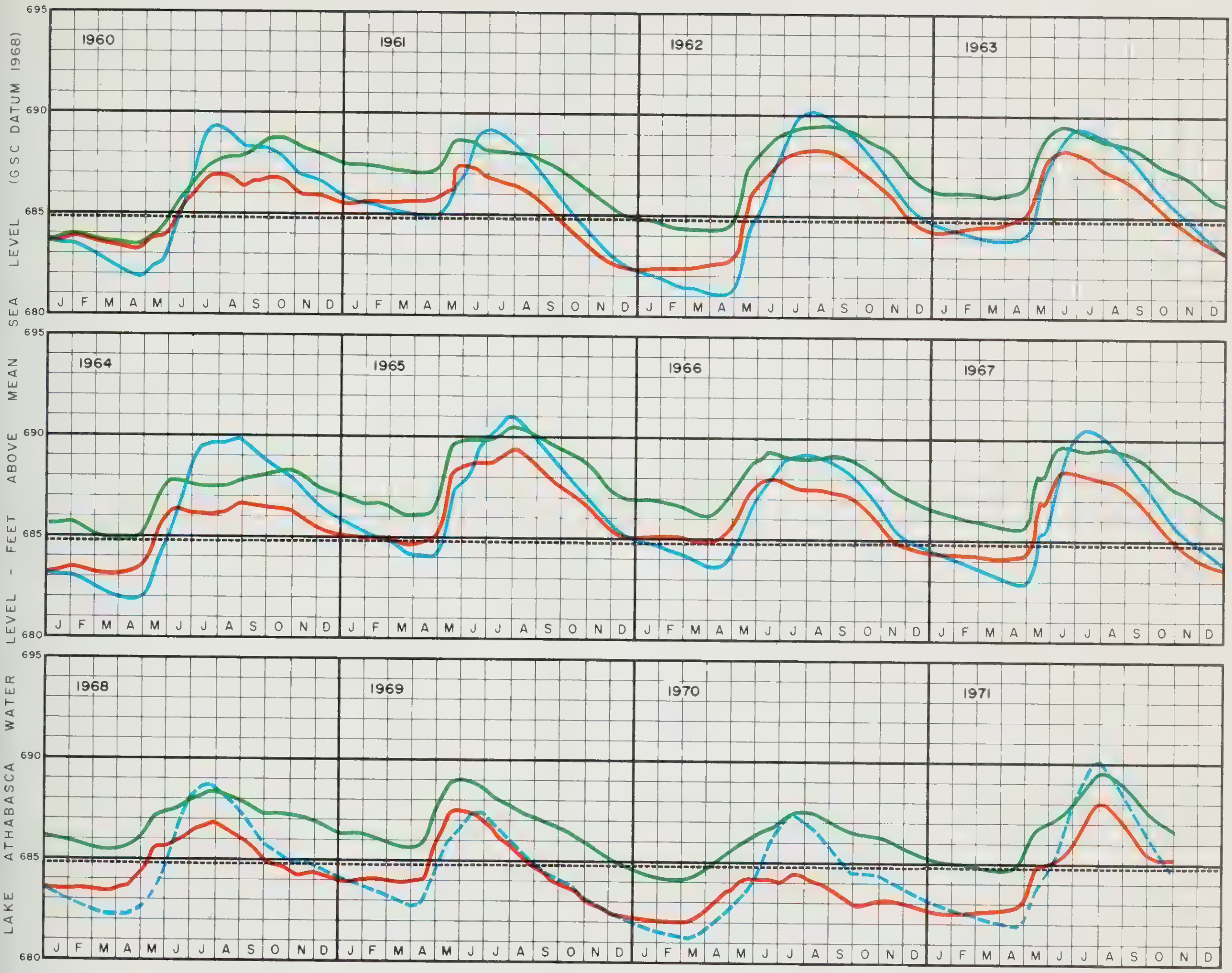
PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION

RIVIERE DES ROCHERS-ALTERNATIVE 2B

ROCKFILL WEIR

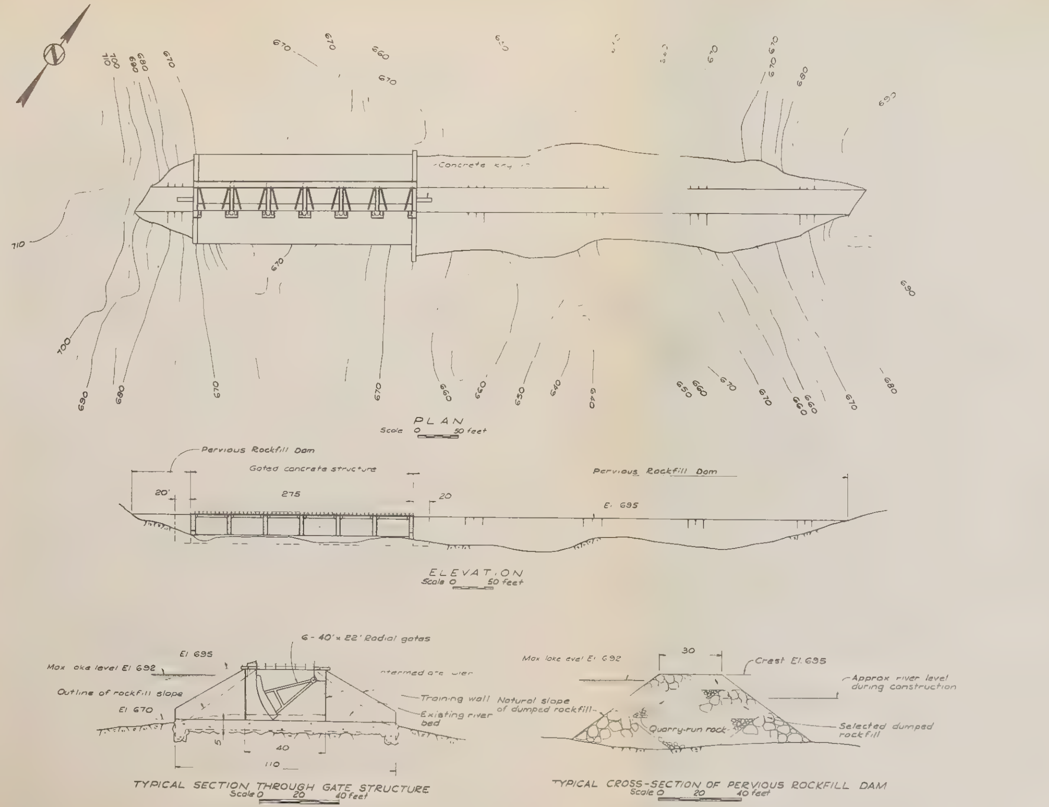
GEPAC, STANLEY & ASSOCIATES LIMITED

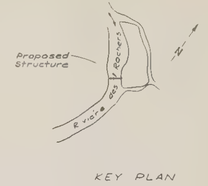
FIGURE F-10



- - - - - - - - Approximate average annual lake level (1930-70)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of Little Rapids weir

FIGURE F-11 Lake Athabasca Hydrographs, Rivière des Rochers, Little Rapids Rockfill Weir





NOTES

1. Rockfill above river level during construction to be end-dumped by trucks & pushed out using earth-moving equipment.
2. Rockfill below river level during constructing may be barge dumped.
3. Selected rockfill to have nominal sizes ranging from 12" to 48" with 50% or more between 24" to 30".
4. All bedrock and rock outcrops located below the gate structure to be excavated to El. 665 and those located in the approach channel upstream or downstream of the gate structure to be excavated to El. 670.

PEACE - ATHABASCA DELTA PROJECT
ALBERTA WATER RESOURCES DIVISION

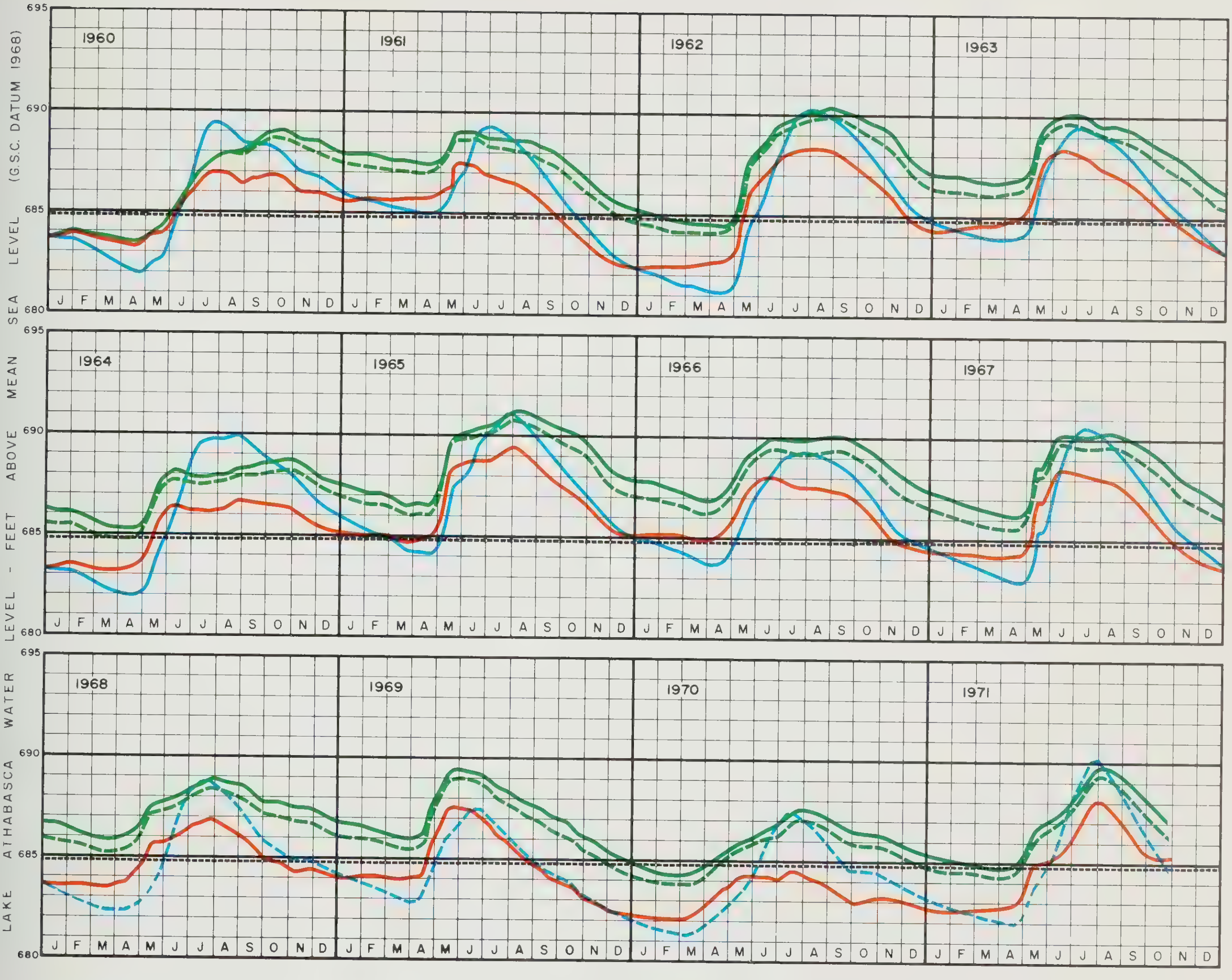
RIVIERE DES ROCHERS - ALTERNATIVE 2C

GATED CONCRETE STRUCTURE AND ROCKFILL DAM

GEPAC, STANLEY & ASSOCIATES LIMITED

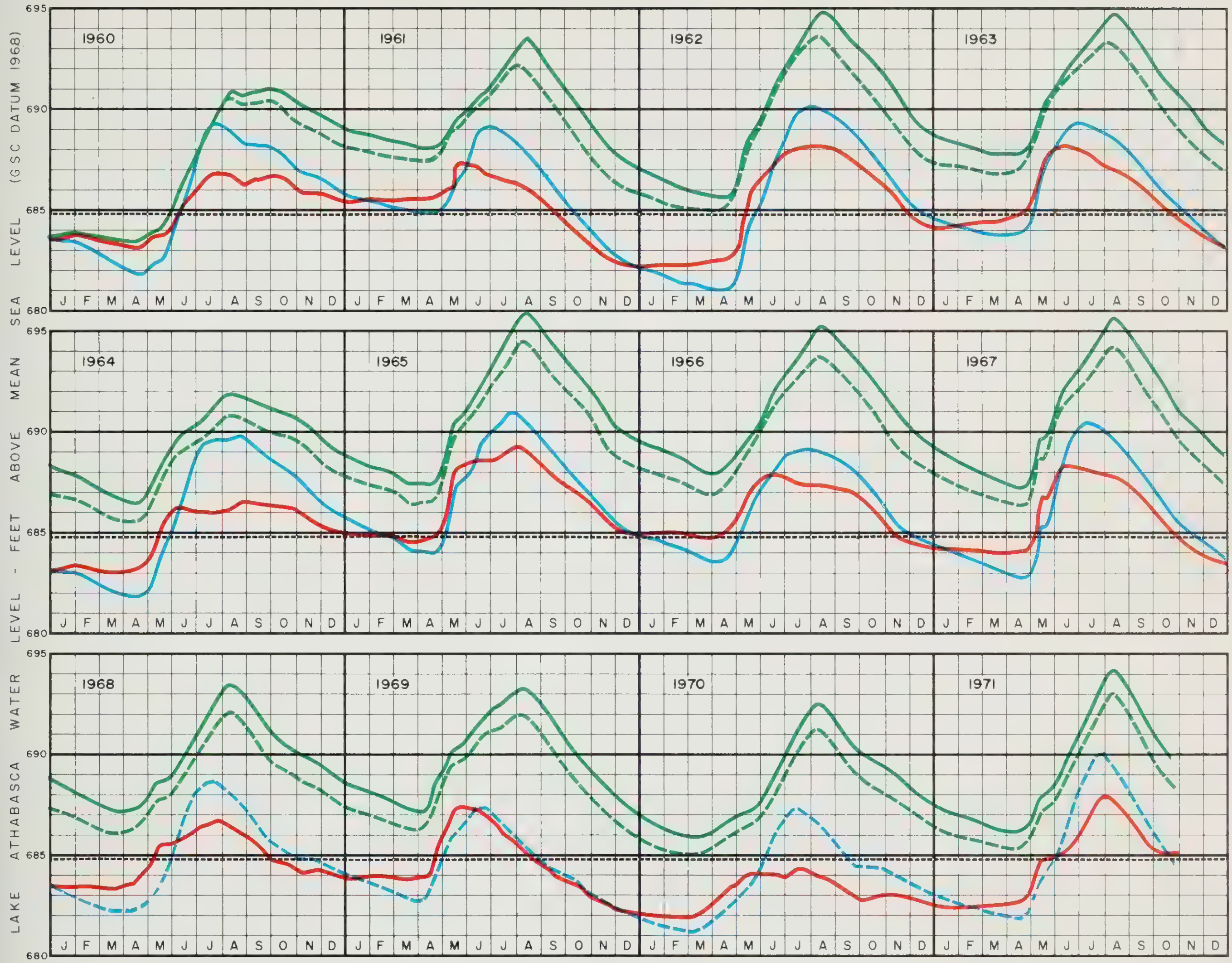
DATE

FIGURE F-12



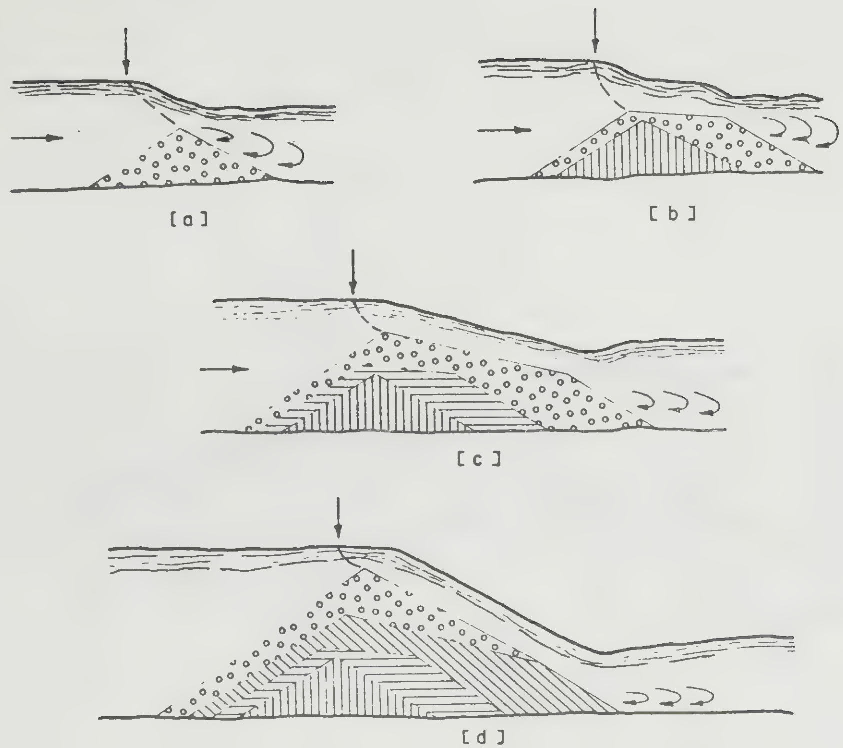
Approximate average annual lake level (1930-70)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of the Little Rapids gated structure (gates always open), option #1
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of the Little Rapids gated structure (gates always open), option #2

FIGURE F-13 Lake Athabasca Hydrographs, Rivière des Rochers
Little Rapids Gated Control Structure, Gates Open

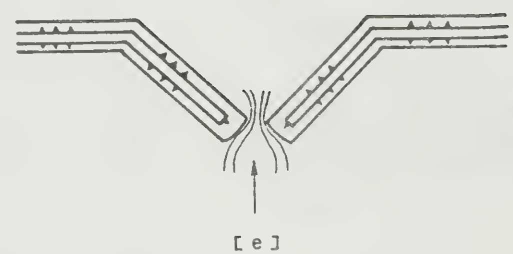


--------- Approximate average annual lake level (1930-70)
Simulation of recorded lake level, option #1
Simulation of lake level, 1968-71, assuming no effect by the Bennett Dam
Simulation of lake level assuming full operation of the Bennett Dam since 1960
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of the Little Rapids gated structure (gates closed), option #1
Simulation of lake level assuming full operation of the Bennett Dam since 1960 and the effect of the Little Rapids gated structure (gates closed), option #2

FIGURE F-14 Lake Athabasca Hydrographs, Rivière des Rochers Little Rapids Gated Control Structure, Gates Closed from May 25-August 13

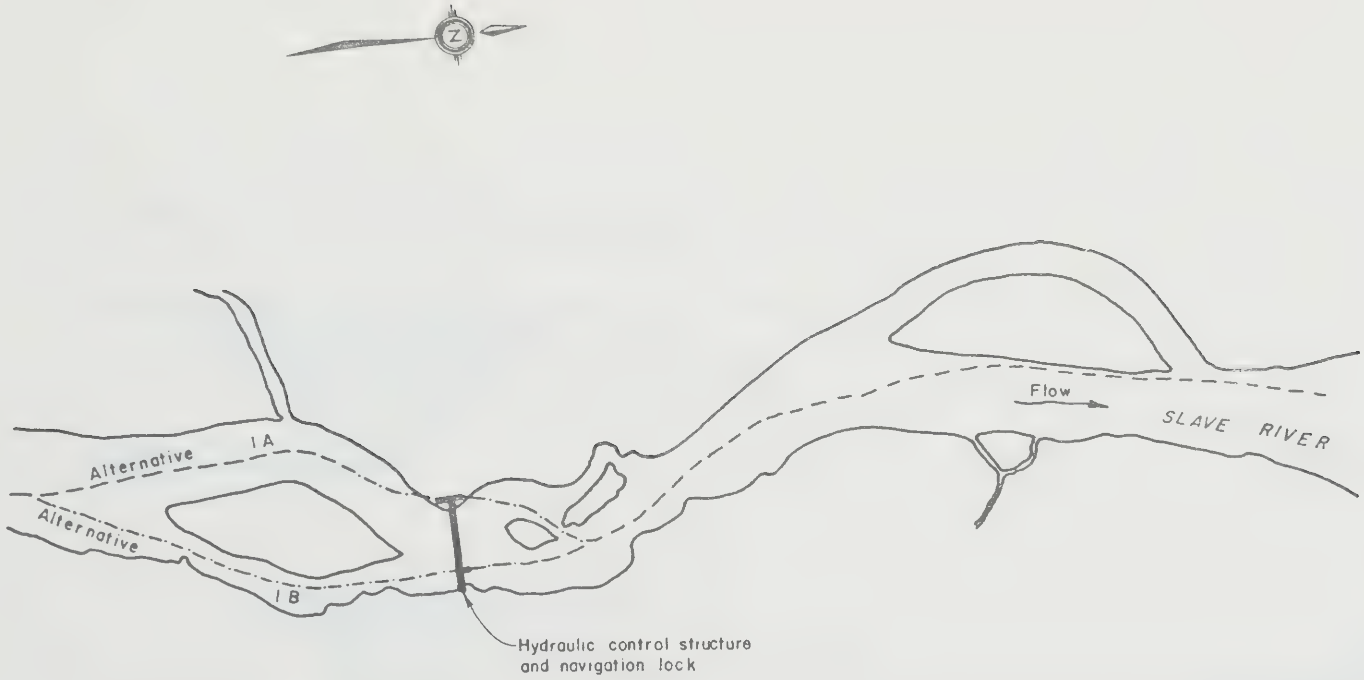


BEHAVIOR OF ROCKFILL DUMPED INTO FLOWING WATER



ANGLED END TIP METHOD

ROCKFILL CONSTRUCTION METHODS
FIGURE F-15



NOTE:

River channel improvement by blasting and dredging may be required on modified navigation route

LEGEND:

– – – – – – Existing navigation route

–·–·–·–·– Modified navigation route

SLAVE RIVER — SITE I

ALTERNATIVE NAVIGATION ROUTES FOR PROPOSED LOCKS

FIGURE F-16

S E C T I O N   F

A P P E N D I X   F - 1

MODEL STUDY OF ROCK WEIRS
PROPOSED FOR THE
ATHABASCA DELTA PROJECT

Submitted by: R. K. Deeprose, P. Eng.
Branch Head
Hydrology Branch

Prepared by: E. K. Yaremko, P. Eng.
River Regime Engineer

G. Mutter
Hydrologist

G. Gehmlich
Technician

October, 1971

Department of the Environment
Water Resources Division
Hydrology Branch

ABSTRACT

During a preliminary study in 1970 of the Peace-Athabasca Delta problem, two different structures were proposed for a rapids section on Riviere des Rochers. The purpose of these structures was to act as a control for flows out of Lake Athabasca. It was suggested at the time that each of the proposed structures should be modelled in order to better determine their hydraulic properties and stability.

Two models were constructed, the first (a rock weir) in December of 1970 and the second (partial rock weir) in August of 1971, using the University of Alberta facilities. Design curves have been derived which permit computation of the backwater effect for a given design, tailwater elevation and outflow.

It appears that a partial weir, emanating out from the left bank for a distance of 550 feet would produce the most desirable range of backwater values.

ACKNOWLEDGEMENTS

Appreciation is expressed to Mr. C. R. Neill of the Alberta Research Council and Mr. A. Charbonneau, University of Alberta, for seeing that facilities for the models were provided, for aiding in the design of the models, and for their suggestions in setting up a test schedule.

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Appendix A		

CHAPTER 1

Model Study of Rock Weirs for the Athabasca Delta Project

1.1 Three possible means of artificially raising the water levels of Lake Athabasca have been suggested in the report "Athabasca Delta Project No. 1" (1). Each of these controls would basically consist of a rock embankment placed in some channel so as to produce a constriction of flow and a consequent upstream increase in water levels. Two of the alternatives of which we are primarily concerned with in this report were to be constructed on Riviere des Rochers at a rapids section about fourteen miles north of Fort Chipewyan. Use of rock embankments in these alternatives was thought to be the most desirable because construction material was locally available in large quantities and the system if it worked would provide the simplest and most economical means of maintaining higher Lake Athabasca levels.

1.2 A detailed description of the two alternatives considered for Riviere des Rochers is provided in the following chapters, but suffice it to say for the present that one alternative consisted of a partial rock weir and the second a complete rock weir. Neither of these proposals lent themselves to easy solution of their hydraulic or stability properties, and as such, it was suggested during preliminary design that hydraulic models should be constructed. These models, would, permit the designer to better estimate the backwater effects which would

(1) Athabasca Delta Project Report No. 1, Alberta Water Resources Division, Department of the Environment, September, 1970.

result from these structures under varying conditions of tailwater and design, and would provide an assessment of the stability of the structure for some given size and gradation of rock.

1.3 Two models were constructed; the first one (rock weir) at the Graduate Hydraulics Laboratory, University of Alberta, and the second one (partial rock weir) at the Mobile-bed Model Facility, University of Alberta Farm, Ellerslie. Construction and operation of the models was under the direction of Mr. C. R. Neill, River Engineer, Research Council of Alberta, and Mr. A. Charbonneau, Laboratory Supervisor, University of Alberta. Interpretation and analysis of the results is presented in the following chapters. The results of this report are intended as a design guide if in the future government policy dictates that a major control structure is feasible or warranted to control lake levels and that the structure used will be of similar character to either of the alternatives discussed in this report.

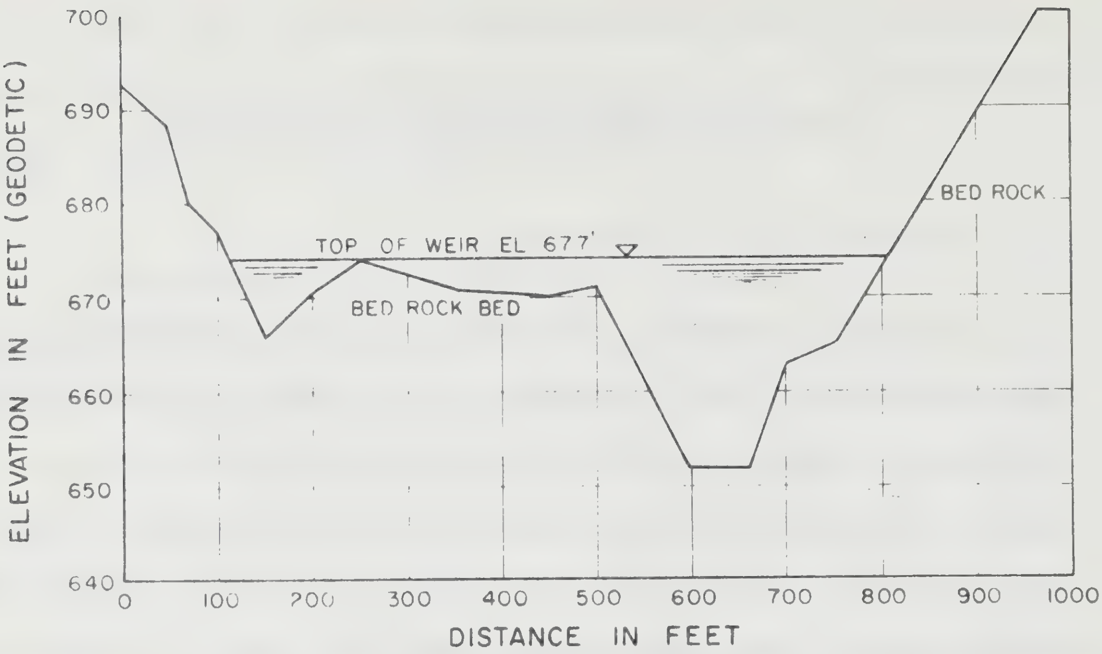
CHAPTER II

Discussion of Model Results for the Rock Weir

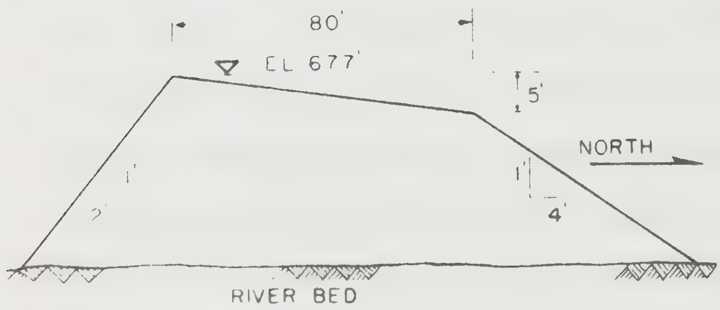
2.1 Tentative Design of Rock Weir

Figure 2.1 provides a description of the weir suggested for the rapids section on Riviere des Rochers. It is likely that the (granite) bedrock which outcrops on the banks also extends across the entire channel so that the weir would apparently be situated within a very stable section. The upstream (south) edge of the weir's crest would be at elevation 677 feet, with the crest then sloping down five feet to the north in a distance of eighty feet. Upstream and downstream side slopes would be 2:1 and 4:1 respectively. The crest was given a slope in hopes of off-setting expected high energy losses by water having to flow over the five foot rocks which would make up the surface of the weir, while the downstream side slope was given a flat 4:1 slope in order to provide some stability safety-factor for the rock under conditions of low tailwater depths and high flows out of Lake Athabasca. Class 2 rock (median size 20 inches or 400 pounds) would make up the permeable core, while one or two layers of five foot (8000 pound) rock would be required on the surface of the weir to provide stability.

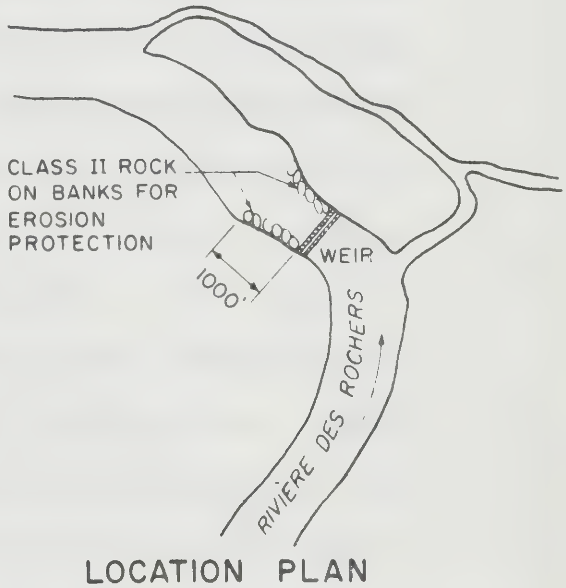
The flow regime of the Slave River is such that the tailwater level below the weir could vary over a height of about twenty-five feet (elevation 672 to 697 feet), which makes a subjective analysis of the outflow regime from Lake Athabasca a very complicated problem. Flows would usually be out of the lake although reverse flow could infrequently occur. This means that the weir has to be high enough to act



CROSS SECTION – RAPIDS – RIVIÈRE DES ROCHERS



END VIEW – ROCK WEIR



LOCATION PLAN

NOTES:

1 CLASS II rock to be used for core of weir, top layer of weir shall be constructed of at least 5' (nominal size, 8000 lbs.) rock.

2 Rock source as for alternative 2A.

3 CLASS II rock (nominal 22" or 500 lbs.)

	100%	smaller	than	33"	or	2000 lbs.
At least	20%	larger	than	24"	or	700 lbs
At least	50%	larger	than	20"	or	400 lbs.
At least	90%	larger	than	11"	or	70 lbs.
	100%	larger	than	6"	or	10 lbs.

ALBERTA DEPARTMENT OF AGRICULTURE
WATER RESOURCES DIVISION
HYDROLOGY
BRANCH

ATHABASCA DELTA PROJECT

ROCK WEIR

GENERAL DESCRIPTION

Scale As Shown | Date Sept 1970 | Sheet 1 of 1

Submitted by: Branch Head	Designed by
Date:	Drawn by V. da Silva
Approved by: Chief Engineer	Checked by
Date:	FIGURE No. 2.1

as a control for outflow over a wide range of flow conditions, and be stable enough to withstand flows in two directions.

2.2 Description of Model

The model was constructed halfway along a sixty foot long, four foot wide flume. Maximum available model discharge was 3 c.f.s. A well-graded crushed granular material for constructing the rock weir was available which had a maximum size of 3/4 inch, so that a prototype to model scale of 40 provided the model material gradation curve shown on Figure 2.2. The difference between the two curves shown was not considered great enough to warrant further refinement towards the gradation curve shown for Class 2 rock. With a four foot wide flume it meant that 160 feet of the prototype was modelled (or approximately twenty percent of the total length of weir) and the maximum prototype unit discharge available was about 188 c.f.s./feet. A tailgate at the outlet of the flume was used to vary the tailwater elevations for various discharges. The stones were hand placed in-the-dry, with a layer of larger stones (1 1/2") being placed for the surface layer of the weir.

The prototype to model scale ratios for various variables are presented below:

Length	-	40
Discharge	-	10,000
Velocity	-	6.34
Time	-	6.34

Hereafter in order to avoid confusion only prototype dimensions will be referred to.

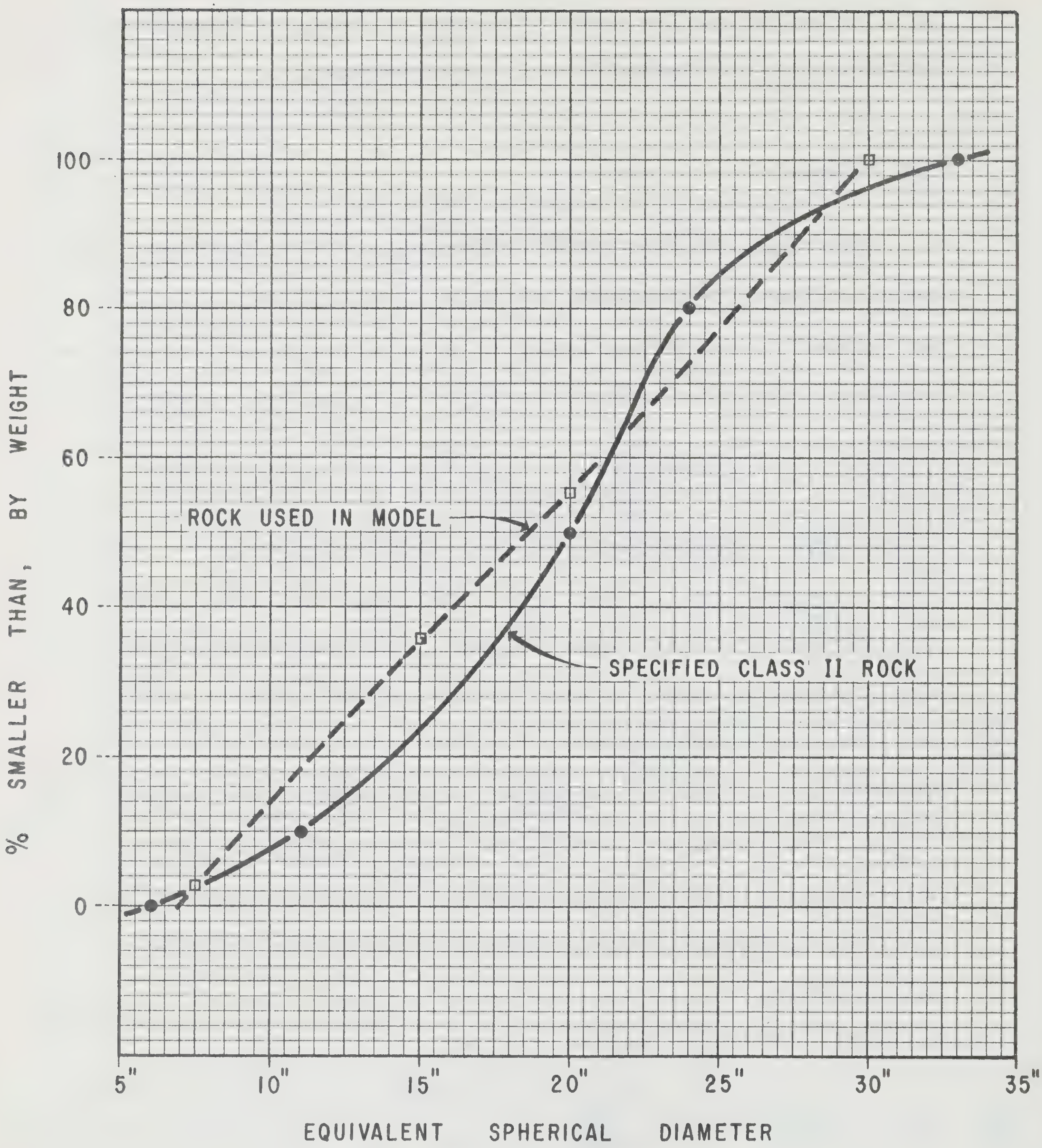


FIGURE 2-2. GRAIN SIZE CURVES FOR CORE OF ROCK WEIR

2.3 Theory of Flow for Weirs

The rock structure being studied is basically a broad-crested weir and in solving for the flow function over it the normal text book procedure is to equate the energy functions between the two sections shown in Figure 2.3, as follows:

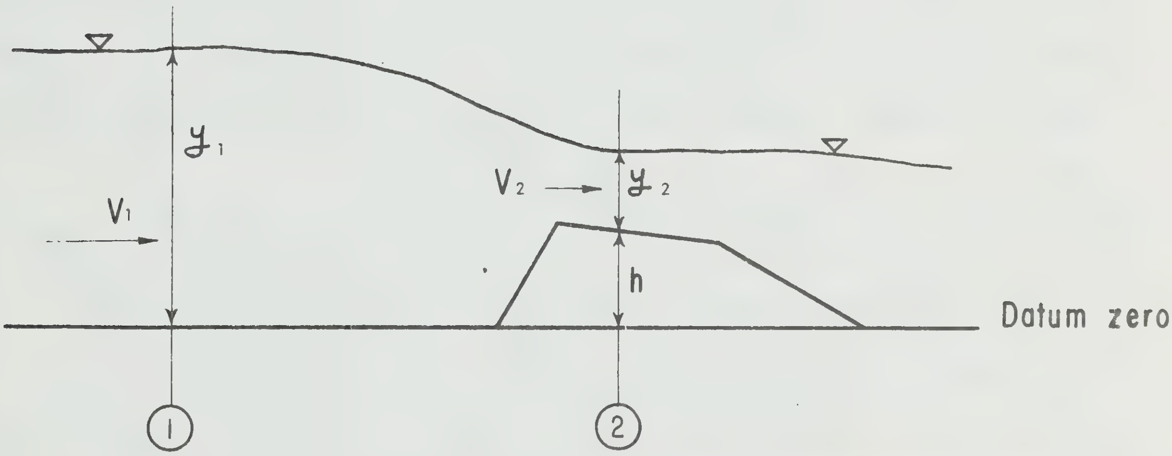


FIGURE 2.3

$$0 + y_1 = \frac{V_2^{\;2}}{2g} + h + y_2 + 0$$

where the approach velocity head $\frac{V_1^{\;2}}{2g}$ has been considered negligible and energy losses between sections 1 and 2 have been neglected. If we let $H = y_1 - h$ and solve for V_2 then;

$$V_2 = \sqrt{2g(H - y_2)}$$

or $\quad q = y_2 \sqrt{2g(H - y_2)} \qquad$ (q = c.f.s./feet width) - (1)

If we assume that section 2 acts as a control so that conditions there are critical then $y_2 = y_c$ and approximately $y_2 = \frac{2}{3} H$. Therefore after

substituting this value for y_2 in Equation 1;

$$q = 3.09\ H^{3/2} \qquad - (2)$$

Backwater upstream of a weir develops once this obstruction is raised to a sufficient height "h" to create a choking effect on the flow. According to a specific energy diagram for a given discharge and with increasing resistance to flow offered by "h", the depth will ultimately reach critical and go no lower no matter how much more the weir is raised. At heights above the one which causes critical flow to develop over the crest the amount of specific energy available is inadequate to maintain "normal" flow, so the water surface would have to rise up and in the process cause a backwater effect.

The model was able to provide enough information to show under what flow conditions the weir would act as a control and to enable development of flow equations of the type given in Equation 2. In general it was accepted that the flow function over a weir where critical flow had developed on the crest was of the form:

$$q = CH^n \qquad - (3)$$

Previous work has indicated that the index "n" should remain fairly close to 3/2 while the constant C will vary with the length of crest, side slopes of the weir and the roughness of the crest surface.

2.4 Test Series I, Interpretation of Results

A model was constructed according to the section shown in Figure 2.1 (see Photograph A.1)*. The height from the base of the weir

* NOTE: Appendix A contains photographs of many of the tests carried out.

to the upstream (south) edge of the weir crest was 25 feet. It should be noted from Figure 2.1 that the river bed on which the weir would be located varies in elevation, being fairly shallow on the left side and deep on the right. It was expected that the flow function over the weir would vary with the depth of approach to the weir, Because the depth varies so much across the channel this initial model used a relatively large approach depth while a second model (Test Series IV) was only constructed 10 feet high in order to observe any differences in the flow function. Discharges between 1.37 c.f.s./foot and 189 c.f.s./foot were tested, with flow going from south to north, and tailwater elevations varying between 670 and 694 feet.

Figure 2.4 is a plot of $q = fns(H_o, TWE)$ where q is the discharge per unit width along the weir, H_o is the difference in elevation between the surfaces above and below the weir and TWE is the tailwater or water surface elevation below the weir. Using this plot Table 2.1 (on the following page) was constructed.

Figure 2.4 permits the solution of flow conditions for most of the possible situations but the data can be broken down into some interesting details. For instance Table 2.1 indicates when critical flow will develop on the crest. With increasing tailwater elevations for a given unit discharge a condition can be delineated where downstream changes are not reflected by changes in the upstream water levels, and this condition occurs when critical flow has developed somewhere on the crest. A broken line has been drawn on Table 2.1 which roughly separates those conditions where the weir acts as a critical flow control, from those where the critical flow has been submerged by high tailwater depths. Thus Figure 2.4 provides two design aides for the assessment of water surface elevations immediately upstream of the weir for the two

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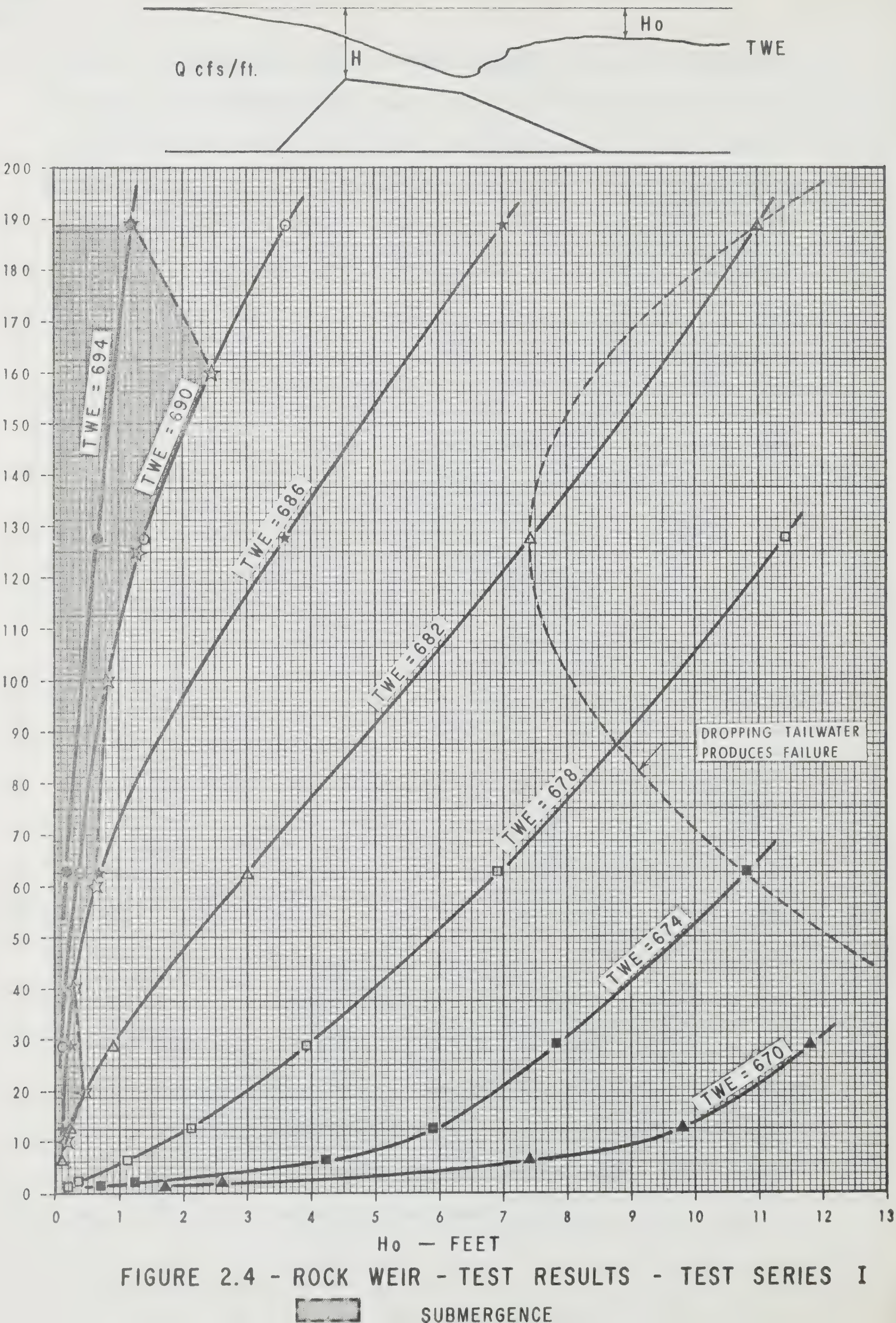


FIGURE 2.4 - ROCK WEIR - TEST RESULTS - TEST SERIES I

TABLE 2.1

Unit Discharge and Upstream Water Surface Elevations

q c.f.s./ft.		10	20	40	60	100	125	160	190
Increasing Tailwater Elevation →	Submergence	694.00	694.05	694.10	694.20	694.5	694.65	694.90	695.20
		690.05	690.10	690.20	690.40	690.8	691.35	692.40	693.70
		686.10	686.20	686.30	686.70	688.3	689.50	691.40	693.10
		682.15	682.4	683.0	684.8	687.5	689.20	691.40	693.10
	Critical Flow on Weir	679.60	681.00	682.80	684.7	687.5	689.20	--	--
		679.30	681.00	682.80	684.6	--	--	--	--
		679.20	681.00	--	--	--	--	--	--
Average		679.50	681.00	682.85	684.70	687.80	689.30	691.40	693.30
- 677		677.00	677.00	677.00	677.00	677.00	677.00	677.00	677.00
(H) Diff(ft)		2.50	4.00	5.35	7.70	10.80	12.30	14.40	16.30

conditions (i.e. critical and non-critical) of flow over the weir. The approximate range where submergence of the weir occurs has been shaded in Figure 2.4 and this occurs during conditions of high tailwater levels. For most conditions, at least in the practical range of variables in the prototype, critical flows will occur and development of Equation 3 for our particular case will be adequate for estimating upstream water levels for various discharges.

At the bottom of each column in Table 2.1 the average upstream water level has been computed for the condition of critical flow on the crest. The differences between these elevations and the elevation of the upstream end of the crest (677 feet) are listed in the last row and

designated as H. By definition for Equation 2 the value of H should be computed at the critical flow section but this was difficult to locate in the model. Also assessment of Equation 1 was not attempted because proper assessment of y_c from the model results was impossible. Figure 2.5 is a plot of the function q = fn(H) where H is defined on Figure 2.4.

$$q = 2.29H^{1.60} \qquad - (3)$$

The index is higher than the 1.50 which occurs for theoretically and straight-forward relatively smooth surfaced broad-crested weirs. The net result of this equation is that it predicts a higher value of H for a given q than might be expected using theoretical values, which must partly be a result of the effect of the rough rock surface making up the crest.

The rock making up the weir remained relatively stable for most test conditions. A zone has been delineated on Figure 2.4 which outlines test conditions where some rocks were displaced. These occurred during high flows and after rapidly dropping tailwater levels. It may be that the rocks which did move were left in an unstable condition during construction. It is unlikely that the conditions which produced a little instability in the model would occur in the prototype. An ice-jam might occur upstream of the Riviere Rochers confluence with the Peace River, which would result in a rapid draw-down of the tailwater level at the weir, but it is doubtful whether the discharge out of the lake would be high enough to move much of the rock. Also in order that the model is more representative of the prototype it would be necessary to pack the rock as snugly as possible during construction in order to represent the hand-placing of rock in the model, and to provide added stability to the structure by increasing the packing factor.

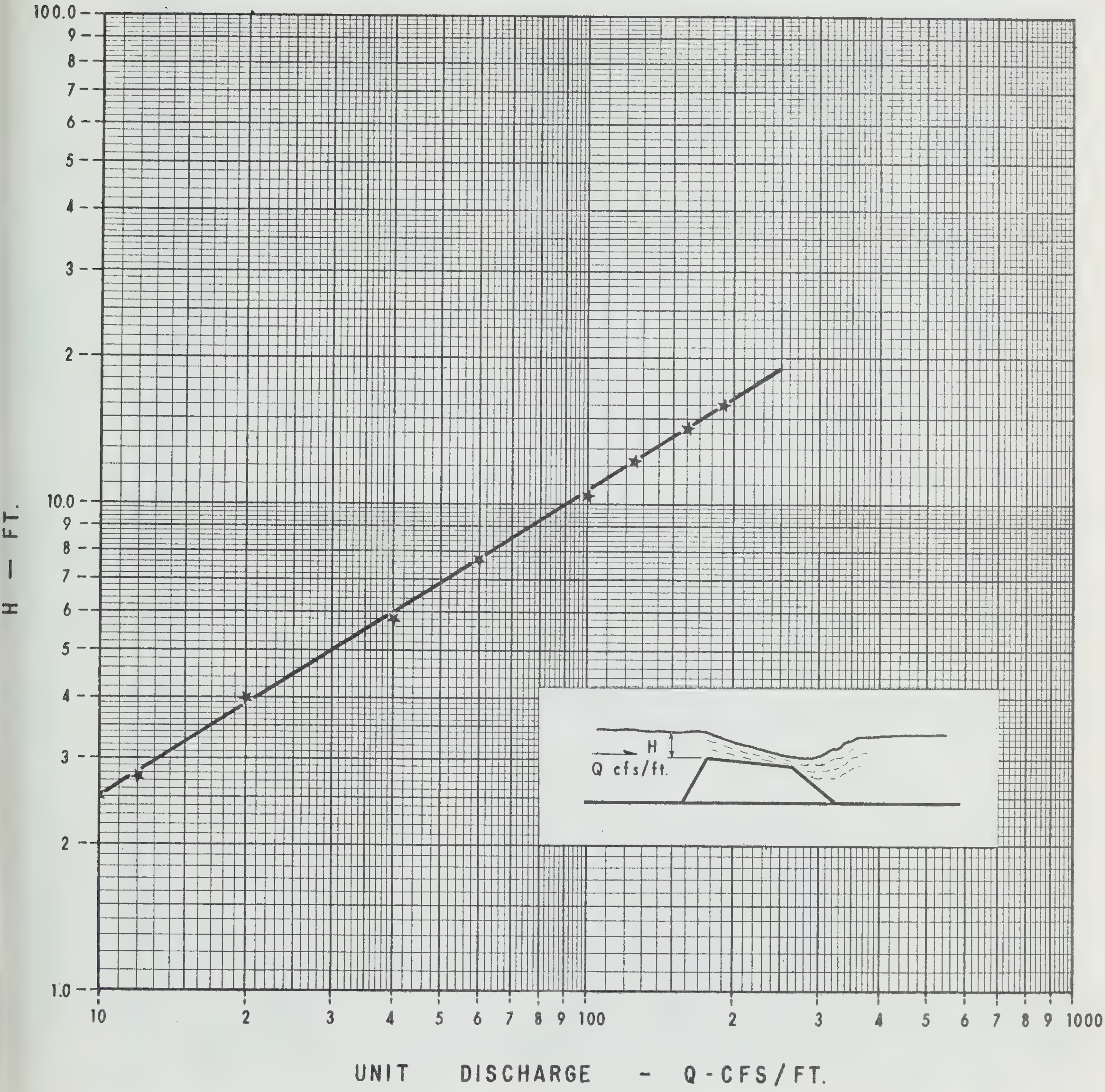


FIGURE 2.5 – HEAD OVER CREST OF WEIR Vs. UNIT DISCHARGE

NO CORE – 25 FT. HIGH

2.5 Test Series II, Interpretation of Results

Using the same model as for Test Series I, a wooden wall was placed through the entire length of weir in order to see if any benefit could be derived from constructing an impermeable core. Figure 2.6 provides a record of the test results, where the variables used were defined for Figure 2.4. Here again as for Table 2.1 we can break this figure down into the following table:

TABLE 2.2

Unit Discharge and Upstream Water Surface Elevations (Impermeable Core)

q c.f.s./ft.		10	20	40	60	100	125	160	190
Increasing Tailwater Elevation	Submergence	694.05	694.05	694.10	694.10	694.40	694.70	695.20	695.70
		691.05	691.10	691.20	691.30	690.90	691.40	692.60	694.00
		686.10	686.20	686.40	686.90	688.60	689.90	691.90	693.60
		682.20	682.60	683.90	685.40	688.30	689.80	691.90	693.60
	Critical Flow	680.30	681.50	683.60	685.40	688.30	689.80	--	--
		680.10	681.30	683.40	685.40	--	--	--	--
		679.90	681.30	--	--	--	--	--	--
Average		680.10	681.30	683.60	685.40	688.40	689.80	692.10	693.70
- 677		677.00	677.00	677.00	677.00	677.00	677.00	677.00	677.00
(H) Diff(ft)		3.10	4.30	6.60	8.40	11.40	12.80	15.10	16.70

The flows have been separated into weir control and submergence conditions, by the broken line through Table 2.2. This information has been transferred to Figure 2.6 where it can be noted that the weir acts

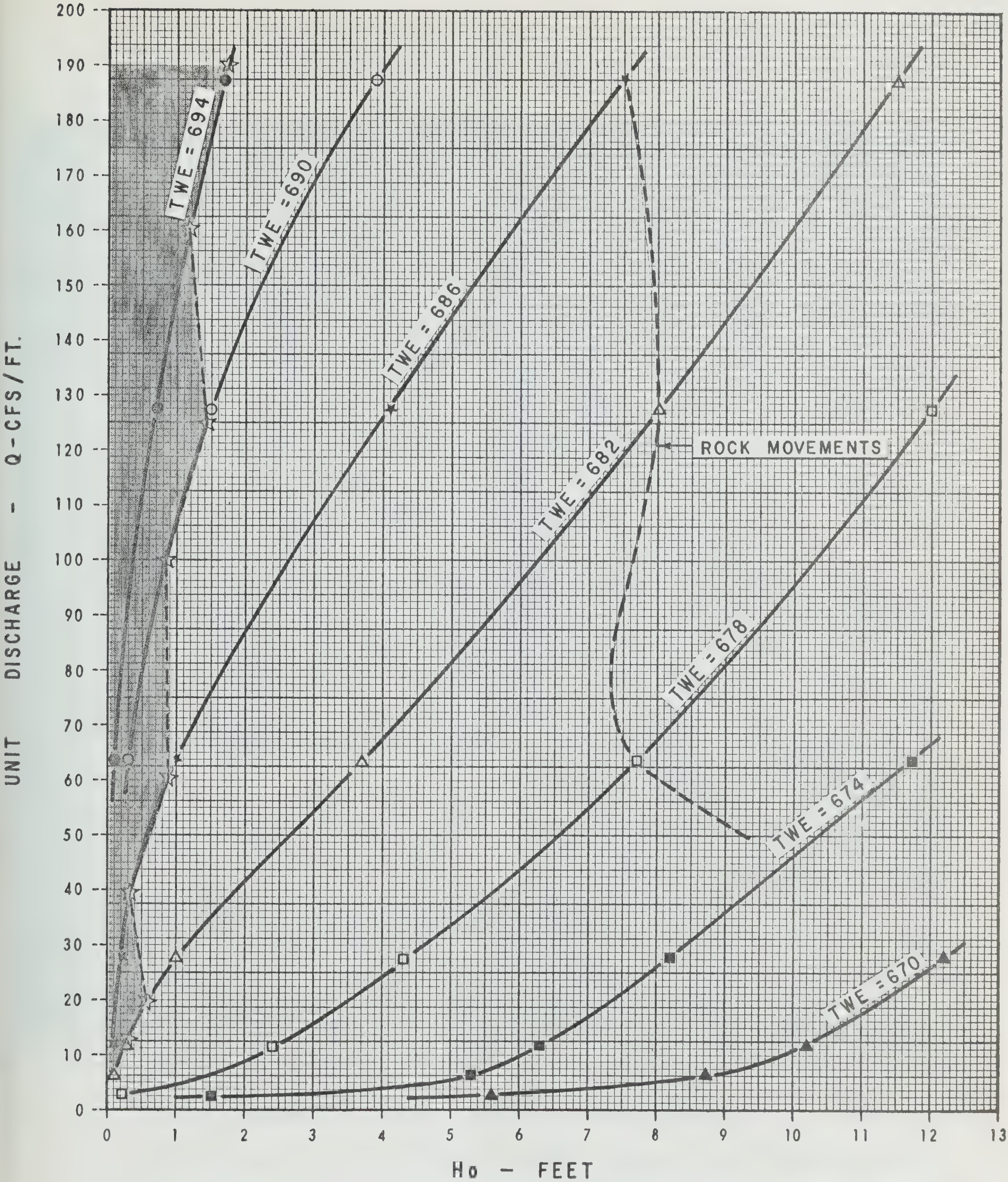


FIGURE 2.6 - ROCK WEIR - TEST RESULTS - TEST SERIES II

IMPERMEABLE CORE


SUBMERGENCE

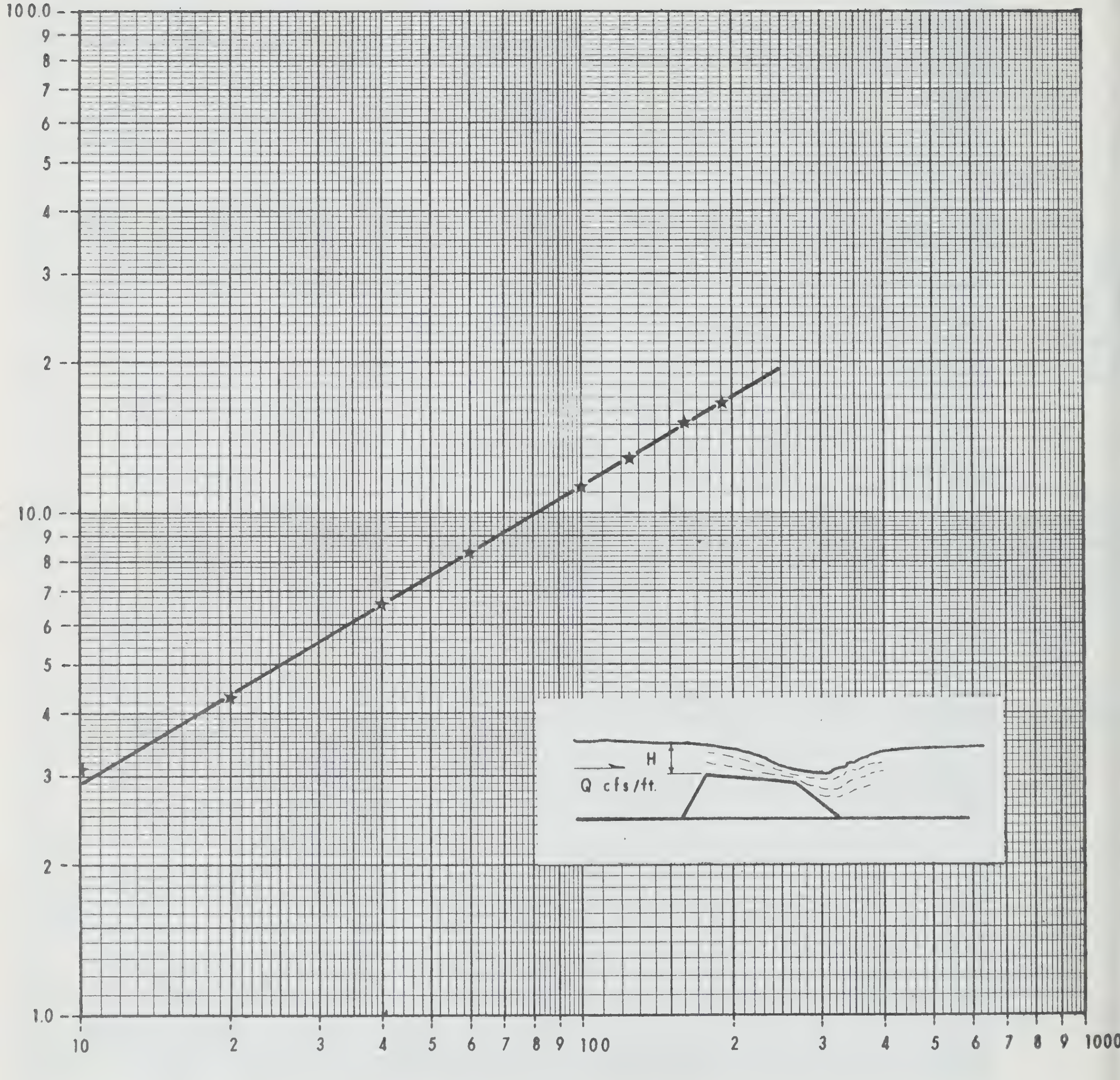


FIGURE 2.7 - HEAD OVER CREST OF WEIR Vs. UNIT DISCHARGE

CORE - 25 FT. HIGH

as a control for most of the possible flow conditions. Values of H and q are plotted on Figure 2.7 and the equation of this line is:

$$q = 1.67H^{1.66} \qquad - (4)$$

Thus for a given "q" and comparing Equations 3 and 4 one would gain a higher backwater effect given by "H" if an impermeable core were used.

A line has also been drawn on Figure 2.6 which outlines a zone where rock movements off the weir are liable to occur. Total failure of the weir did not occur during any of the test conditions given on this line but rather local rocks moved a few feet which might indicate incipient instability of the rock or possibly a few rocks on the model had been placed in an unstable position.

2.6 Test Series III, Interpretation of Results

It is known that under certain combinations of high Peace River flows and low lake levels water will begin running into Lake Athabasca from the Peace River primarily through Riviere des Rochers and normally in June. The amount of flow is not usually very great, averaging around 18,000 c.f.s. in June during pre-Bennett Dam days. A flow of 70,000 c.f.s. is estimated to have occurred in June of 1964 but this was rather exceptional, and with the modified Peace River peaks, it is likely flow reversal in the future will occur even less frequently and in smaller amounts than in the past. However, because flow reversal is still a possibility, the model for the previous tests (see Photograph A.2) was reversed, in order to check its stability and to determine the flow function for it. Figure 2.8 is a plot similar to Figures 2.4 and 2.6 and Table 2.3 has been derived from it.

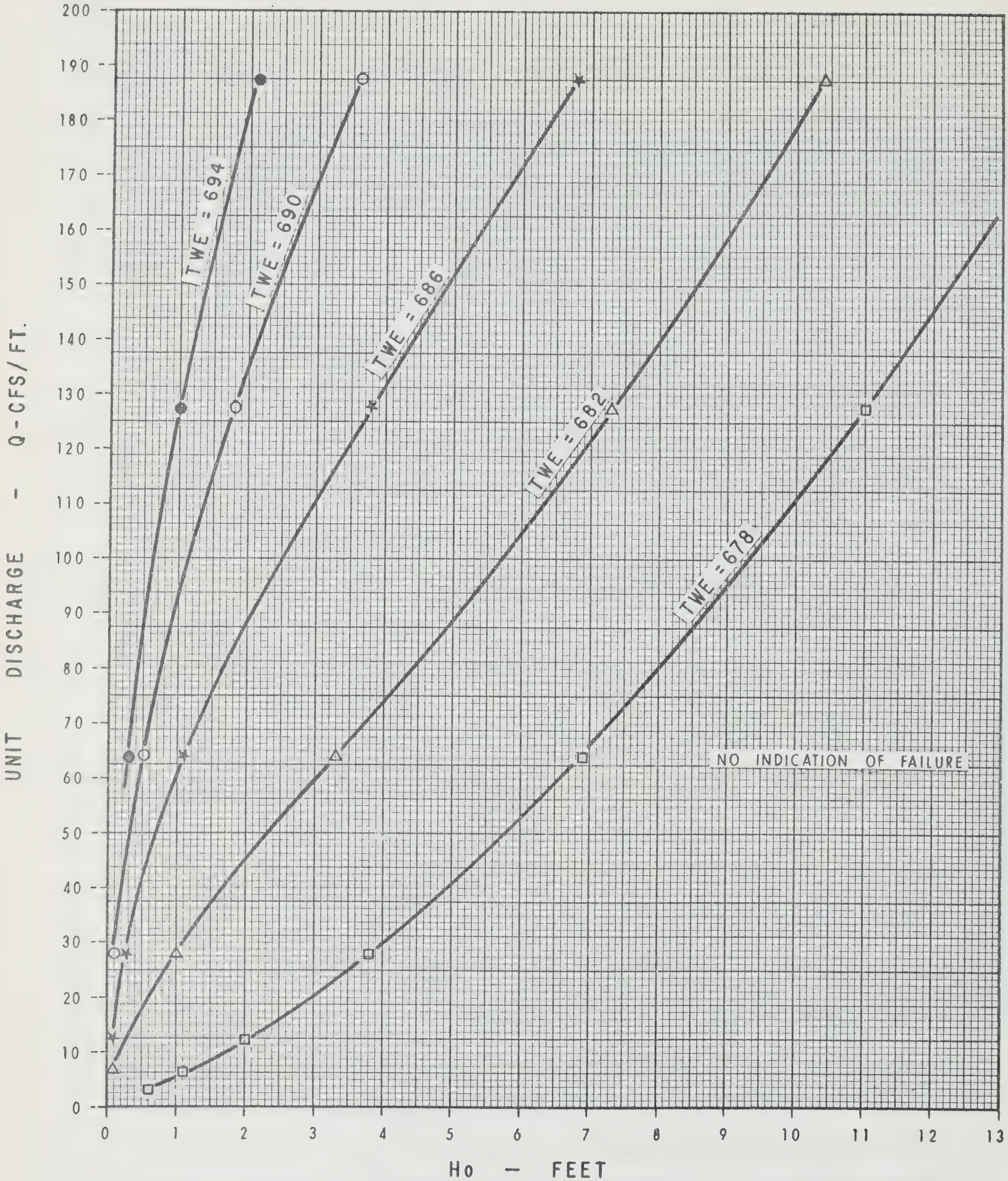


FIGURE 2.8 - ROCK WEIR - TEST RESULTS - TEST SERIES III

REVERSE FLOW - NO IMPERMEABLE CORE

TABLE 2.3

Unit Discharge and Upstream Water Surface Elevations (Flow Reversal)

q c.f.s./ft.	10	20	40	60	100	140	160	190
Increasing Tail-water Elevations ↑	693.90	694.00	694.10	694.25	694.60	695.20	695.50	696.10
	690.00	690.10	690.20	690.45	691.10	692.10	692.70	693.70
	686.10	686.20	686.50	687.00	688.50	690.30	691.30	693.00
	682.20	682.60	683.70	685.00	687.70	689.90	691.00	692.50
	679.80	681.00	683.00	684.60	687.30	689.60	690.80	692.30

It appears that in general the structure will not behave as a control, i.e. critical flow will not develop over the structure. A dashed line delineates a set of flow conditions where critical flow was close to occurring but this was during a range of high flows and low lake level conditions which are never likely to occur in the prototype. A box has been drawn around the practical range of consideration.

None of the test conditions imposed caused rock to become unstable so reverse flow is not expected to cause any stability problems for the proposed structure.

2.7 Test Series IV, Interpretation of Results

This last series of tests was carried out to see if any difference would result in the flow function over the rock weir if the depth of approach was less than the 25 feet used in the first two test series. The rock weir was constructed 10 feet high, with a permeable core, and the same flow conditions as for Test Series I were observed.

Figure 2.9 presents the results of the observations and Table 2.4 has been derived from it.

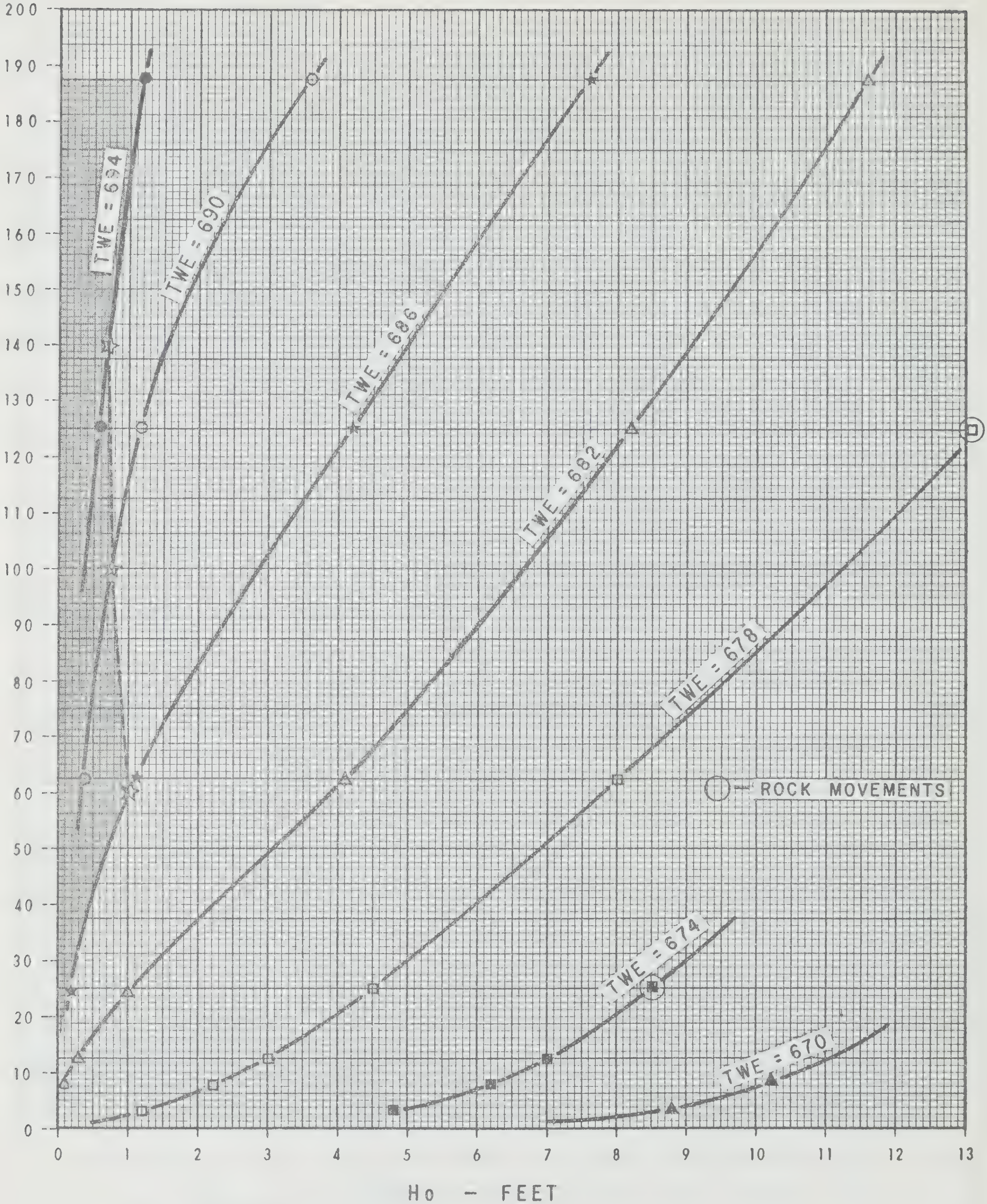


FIGURE 2.9 - ROCK WEIR - TEST RESULTS - TEST SERIES IV

SUBMERGENCE

TABLE 2.4

Unit Discharge and Upstream Water Surface Elevations (10' high weir)

q c.f.s./ft.		10	20	40	60	100	140	160	190
Increasing Tailwater Elevation ↑		694.15	694.05	694.05	694.10	694.40	694.70	694.90	695.50
	Submerged Flow	690.10	690.10	690.20	690.40	690.80	691.50	692.30	693.70
		686.10	686.15	686.50	687.00	688.80	691.00	692.10	693.80
		682.10	682.70	684.20	685.90	688.60	691.00	692.10	693.80
		680.70	682.00	684.00	685.80	689.20			
	Critical Flow	680.70	682.00	683.90					
		680.70	682.00						
Average		680.70	682.00	684.00	685.90	688.80	691.20	692.00	693.80
- 677		677.00	677.00	677.00	677.00	677.00	677.00	677.00	677.00
H Diff (ft)		3.70	5.00	7.00	8.90	11.80	14.20	15.20	16.80

Conditions where critical flow has developed on the weir have been delineated by the broken line in Table 2.4. This same line has been drawn on Figure 2.9 and shows that the weir will not act as a control for only a very few combinations of flow and tailwater depths, i.e. at very high flows and high tailwater depths. The "head" differences H during times when the weir is a control have been computed above and the function q = fn(H) is plotted on Figure 2.10. The equation of this line is:

$$q = 1.03H^{1.85} \qquad - (5)$$

which permits the computation of the resultant upstream water surface elevation for any tailwater condition (outside the shaded area in Figure 2.9) and flow.

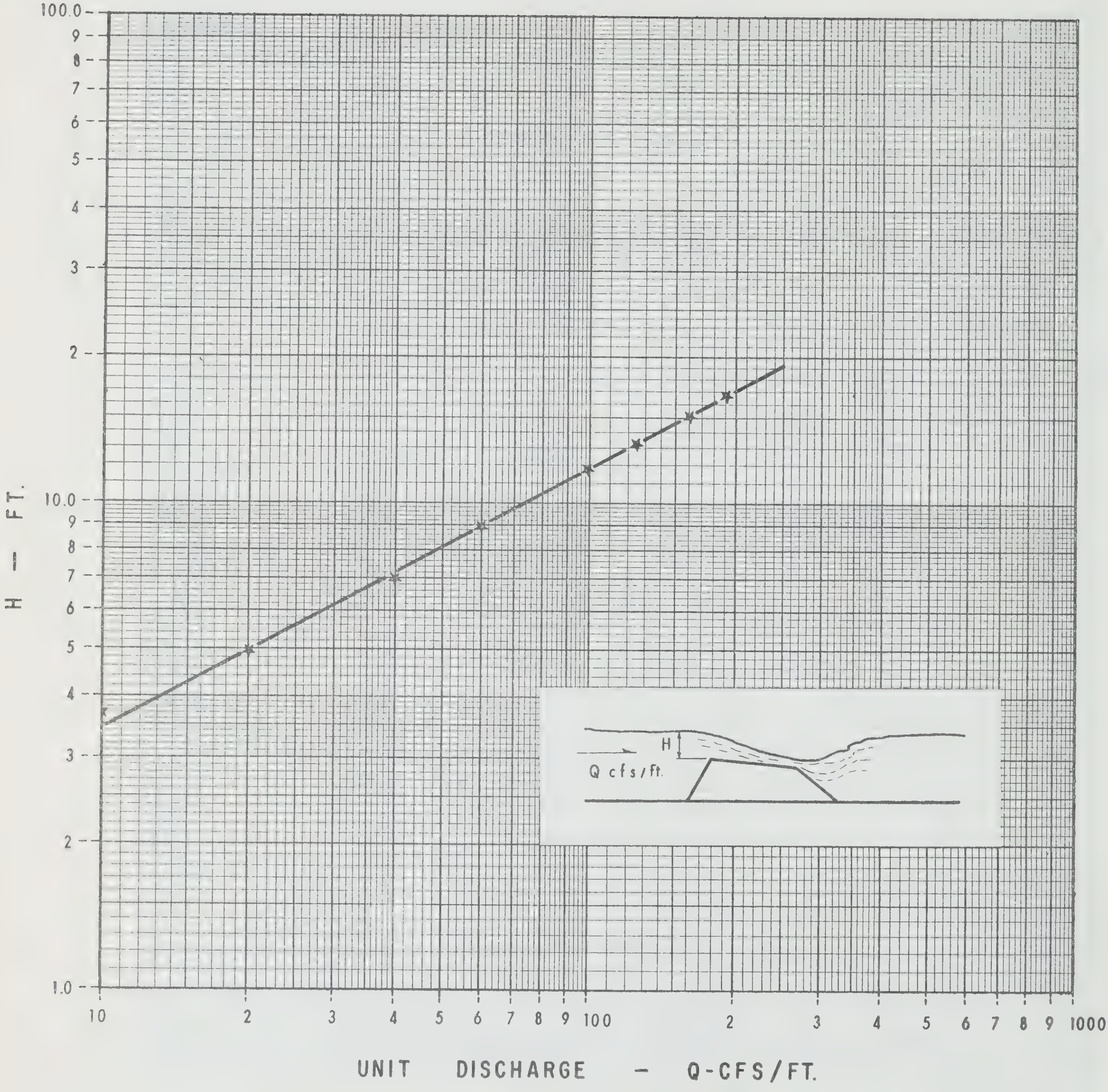


FIGURE 2.10 - HEAD OVER CREST OF WEIR Vs. UNIT DISCHARGE

NO CORE - 10 FT. HIGH

The structure was completely stable during testing except for the two situations shown on Figure 2.9. Both of these cases occurred during low tailwater conditions where rock moved away from the toe of the structure. The amount of rock which moved was not great and it is not felt that the structure was in any condition of imminent failure.

2.8 Profiles

Longitudinal water surface profiles were measured for every test and in general these fell into three categories, as illustrated in Figure 2.11.

The first case shows a rapid drawdown of the water surface over the weir crest, flow along the crest at critical or supercritical conditions, and a rapidly undulating water surface developing downstream (form of hydraulic jump) of the weir. This was the most common situation during testing and represents the case where the rock weir acted as a control structure.

The second case occurred when the flow control condition became submerged. This featured a small lowering of the water surface over the weir, without too much turbulence resulting.

Thirdly, was the case of low lake inflow and low tailwater, which results in a small depth of water percolating through the rock on the surface of the weir.

2.9 Conclusions

The three equations derived for flow over a rock weir are as follows:

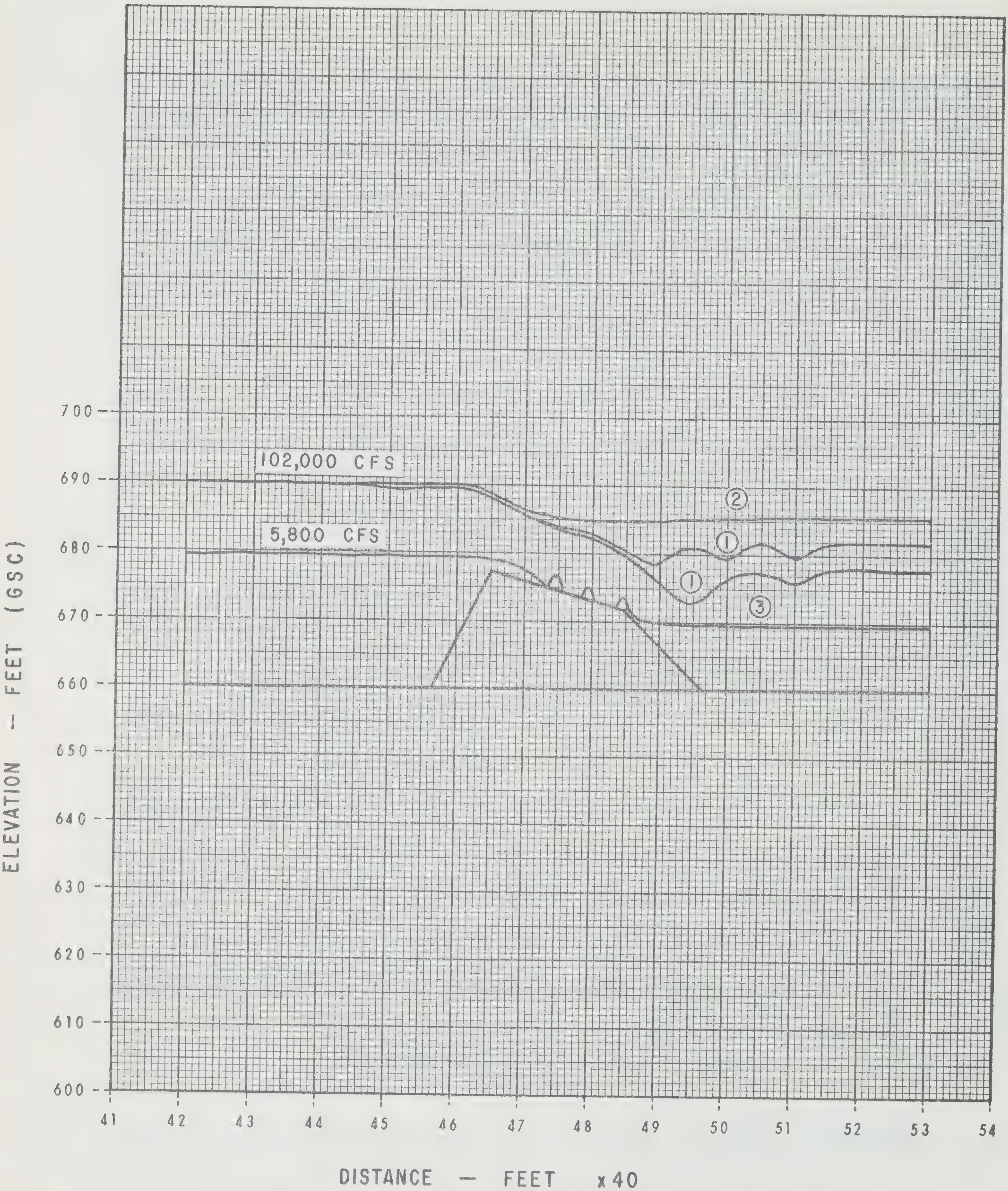


FIGURE 2.11 - TYPICAL WATER SURFACE PROFILES

Equation 3. 25' high weir, permeable core; $q = 2.29H^{1.60}$

4. 25' high weir, impermeable core; $q = 1.67H^{1.66}$

5. 10' high weir, permeable core; $q = 1.03H^{1.85}$

In actual fact, all of these equations produce H values for given unit discharges that are not too different. For instance if the unit discharge were 100 c.f.s./ft., each of the above equations would give H values of 10.4, 11.6 and 11.8 feet respectively.

Figures 2.4, 2.6 and 2.8 roughly delineate prototype conditions where the control effect of the weir becomes submerged. It appears that supercritical flow will occur on the crest for most of the possible flow conditions and that the specified material size will be adequately stable. There will have to be compromise between Equations 3 and 5 since the shallow approach condition has some effect on the amount of backwater.

CHAPTER III

Model Study of Partial Rock Weir

3.1 Nature of the Study

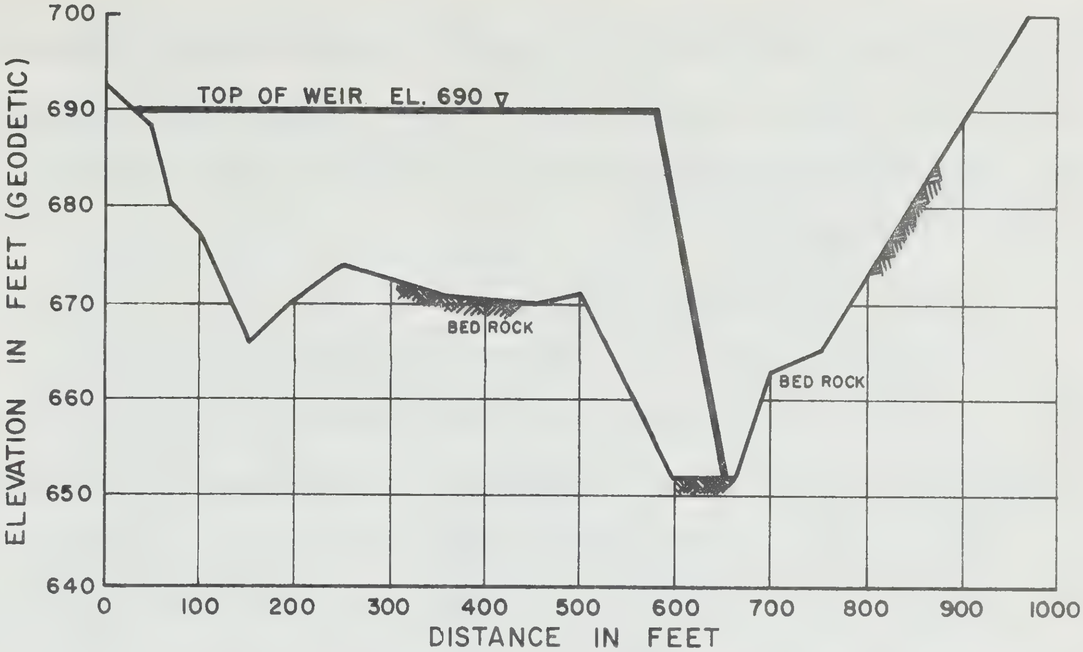
Figure 3.1 provides the general details of the notched weir which would be located at the same site as has been previously described for the broad-crested weir. The fact that a notch is employed to pass low flows precludes the possibility of studying a model of a narrow section of the weir (as was the case for the broad-crested weir). As such, it was necessary to construct the entire weir on a model of the river reach which contains the natural (bedrock) control point.

The subsequent model study had several objectives to fulfill: (1) to determine the stage-discharge relationship for the natural section; (2) to determine the effect of rock size, dumping rate, etc., on the construction of the weir; (3) to determine the relationship (for each variation of the partial weir) among headwater elevation, tailwater elevation and discharge; (4) observe flow velocities in the constriction so as to determine the possibility of navigation.

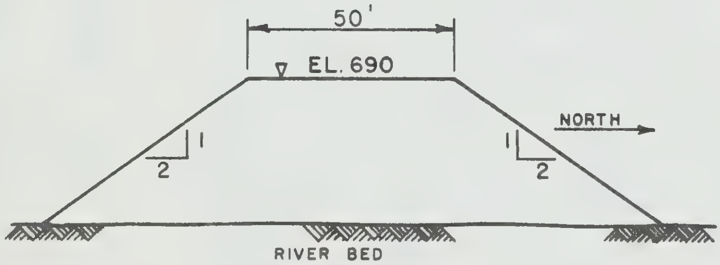
3.2 Laboratory Facilities

3.2.1 Apparatus

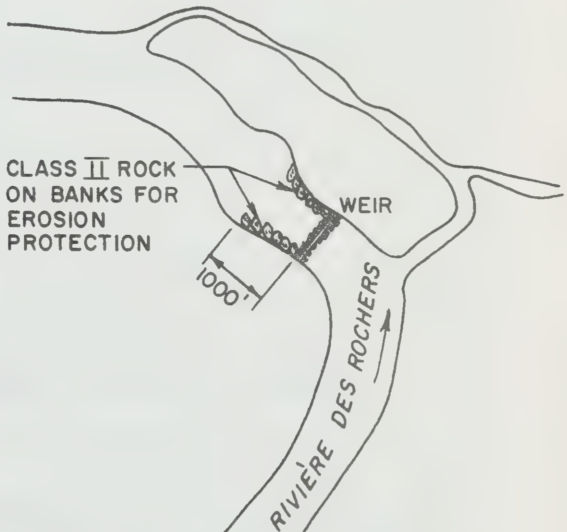
The natural river bed was constructed of sand which was contoured according to surveys conducted of the prototype, and was stabilized by a thin layer of cement. The closed system consisted of a headtank, the river tray, a large sump and two pumps with a combined capacity of approximately 1.5 c.f.s. The flow was regulated (by means of a butterfly valve) as it discharged into the headtank and over a calibrated sharp-crested weir. Tailwater elevation was controlled by the adjustment of a hinged tailgate.



CROSS SECTION – RAPIDS – RIVIÈRE DES ROCHERS



END VIEW – PARTIAL ROCK WEIR



LOCATION PLAN

NOTE:

1. CLASS II rock and CLASS III rock to be for core of weir, top two layers to be constructed of 36" rock.
2. Rock source as for alternative 2A
3. CLASS III rock specifications:

100% smaller than 51" or 7000 lbs.
At least 20% larger than 36" or 2500 lbs.
At least 50% larger than 30" or 1500 lbs.
At least 90% larger than 17" or 250 lbs.
At least 100% larger than 10" or 50 lbs.

ALBERTA DEPARTMENT OF THE ENVIRONMENT
WATER RESOURCES DIVISION
HYDROLOGY
BRANCH

H135G

ATHABASCA DELTA PROJECT

PARTIAL ROCK WEIR

GENERAL DESCRIPTION

Scale As Shown | Date Oct. 1971 | Sheet 1 of 1

Submitted by
Date
Approved by
Date
Designed
Drawn by
Checked by

FIGURE No. 3.1

Electronic gauges were employed to monitor the levels of the headwater, the tailwater, and the stage of the flow over the calibrated triangular weir. The apparatus described above are illustrated in Figures A-9 to A-11 of the appendix.

3.2.2 Determination of Model Scales

As the pump capacity was limited to approximately 1.5 c.f.s. and as it was thought possible to simulate a prototype discharge in excess of 150,000 c.f.s., the scale of discharge (Qs) was fixed at 1:100,000. As the force of gravity was common to model and prototype (and because the Froude Number in this model must be maintained as unity) the length scale (Ls) was necessarily fixed as:

$$L_s = Q_s^{2/5} = 1:100$$

Other relevant quantities could then be determined:

$$t_s = \text{time scale} = \frac{L_s^3}{Q_s} = 1:10$$

and

$$V_s = \text{velocity scale} = \frac{L_s}{t_s} = 1:10$$

3.2.3 Selection of Material for Weir Construction

For the purpose of this study, the material used in the weir construction will be considered as having been a part of the laboratory apparatus. It was manufactured according to the specifications of Figure 2.1 and Figure 3.1 from 100% crushed rock. The sieve curves of the specified and actual gradations are illustrated by Figure 3.2. Both Class II and Class III material were employed in the weir construction. Rip-rap was provided for in the form of 36" (minimum) rock. The material described above is shown in Figure A-12.

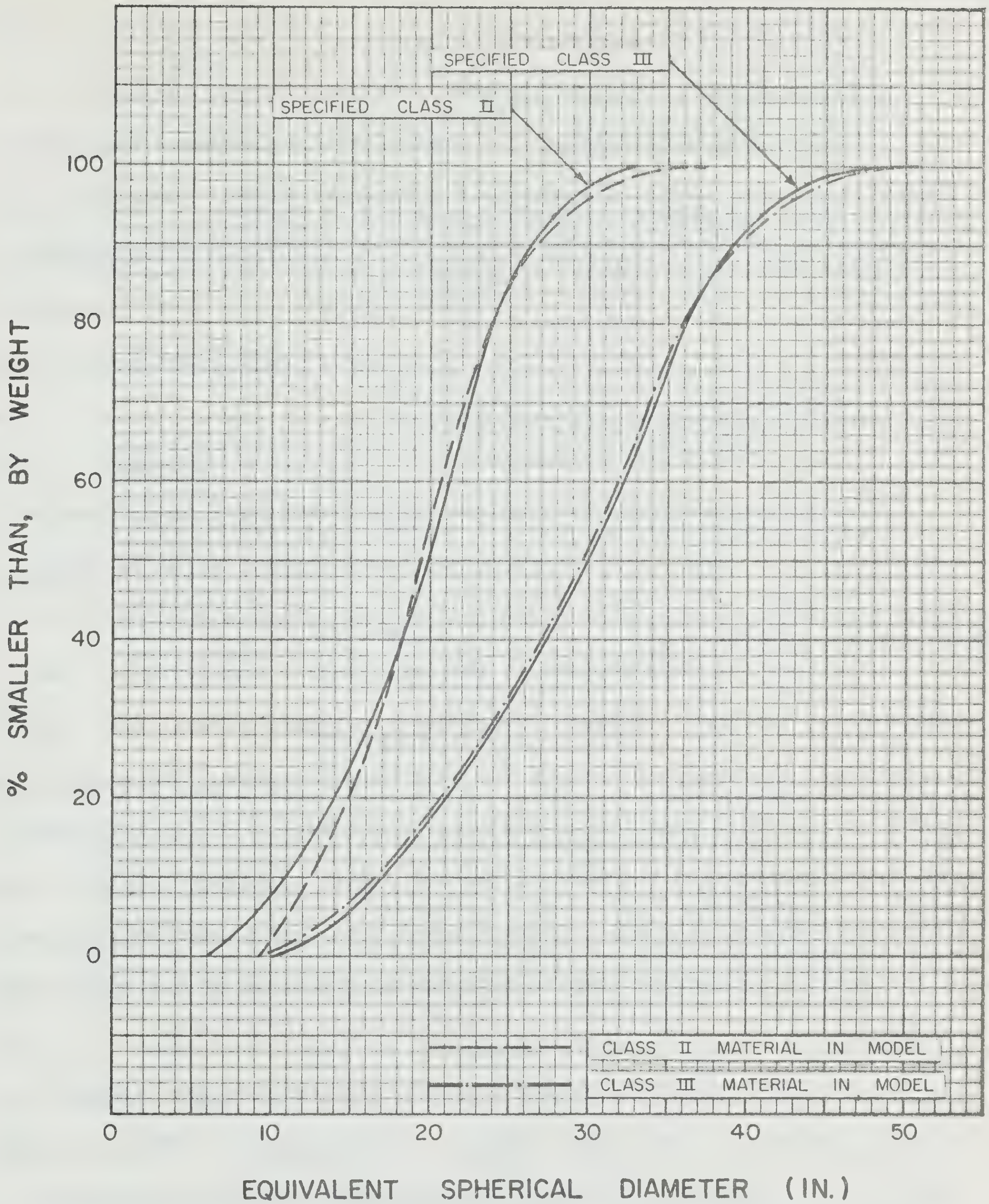


Figure 3.2

GRAIN SIZE CURVES FOR MATERIAL USED IN CORE OF PARTIAL ROCK WEIR

3.3 Details of Partial Rock Weir

3.3.1 Physical Characteristics

All of the variations of the notched weir shared some common general features. Crest elevation was maintained at 690' (Geodetic). Top width was 50' while sideslopes were 2:1 on upstream and downstream faces and on the nose. Class II rock was employed until erosion began to occur. The core of the weir was then completed with Class III material followed by placement of rip-rap.

3.3.2 Method of Construction

An attempt was made to simulate the end-dumping procedure which would be used to construct the prototype. Once erosion began to occur, a small container was used to place the core material on the end of the weir. The rock was then dozed into the water with a small trowel. The method which was most successful, when erosion became severe, was to push the rock off the upstream face of the weir near the nose. The material then tended to roll into position on the nose of the weir. If the rock were launched directly onto the nose of the weir, the trajectory resulted in the particles being carried some distance downstream, and distorting the shape of the weir. The average dumping rate was in the order of six cubic yards per minute.

The flow conditions during the weir construction were selected as being typical for the winter months. A discharge of 35,000 c.f.s. was chosen and the tailwater elevation was maintained at 673.0' (Geodetic).

3.4 Test Series V, Interpretation of Results

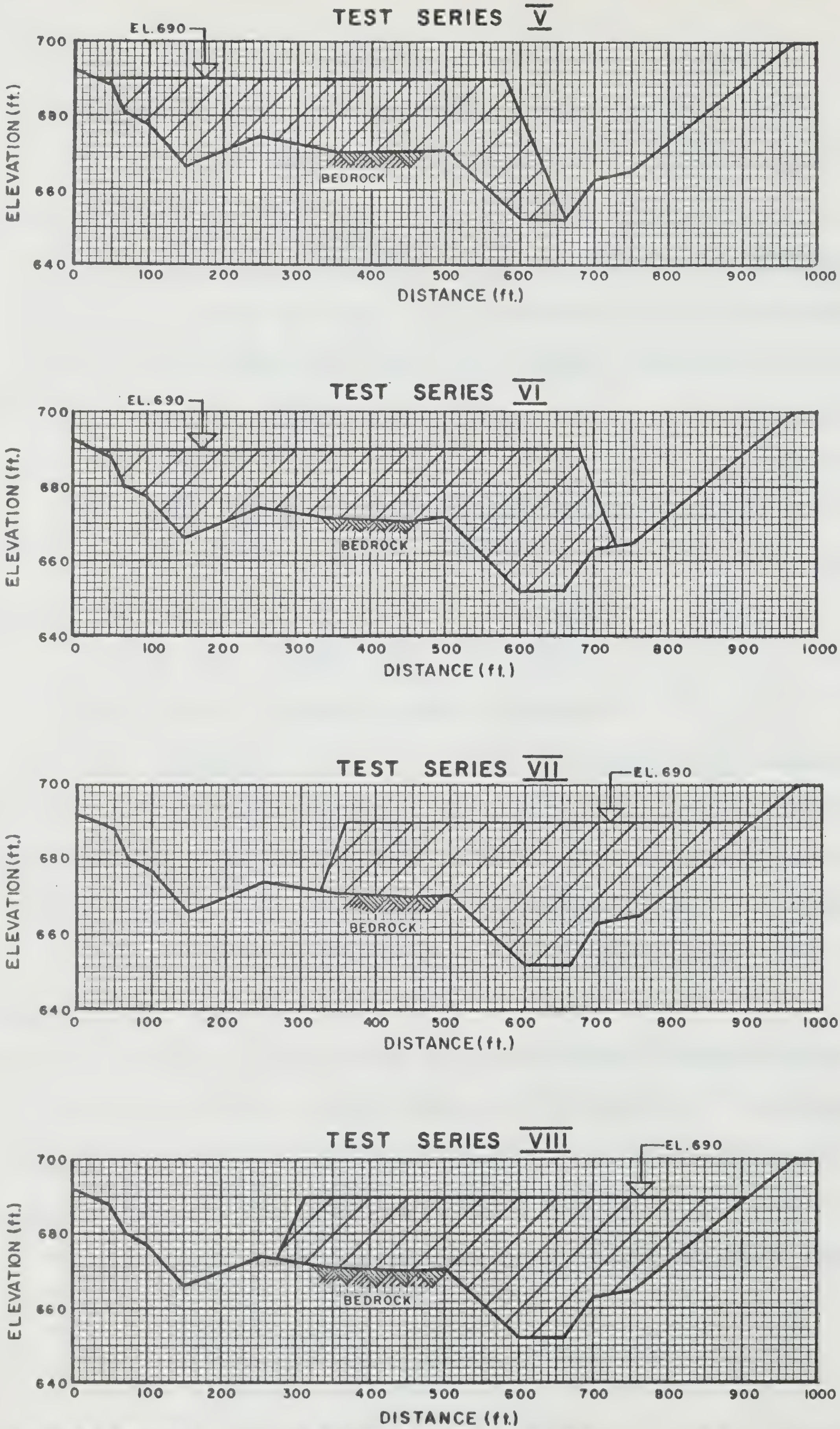
This series was devoted to the construction and testing of a partial weir extending 550' from the left bank (see Figure 3.3). The weir is shown in various stages of construction, in Figures A-13 to A-18. In subsequent test series, the channel was further constricted and the performance of a weir extending from the right bank was also evaluated. The resulting functions, which describe the flow conditions over the weir, were intended for use in selecting the most advantageous variation of the partial rock weir.

In Test Series V, the ranges in measured quantities were as follows:

Discharge	-	15,000 c.f.s. to 100,000 c.f.s.
Tailwater elevation (GSC)	-	672' to 688'
Headwater elevation (GSC)	-	675.6' to 694.0'

The data have been assembled in Table 3.1 and the relationship among the three measured variables is illustrated graphically by Figure 3.4. Due to the discontinuous nature of the notched weir, it was impossible to simplify the analysis of the flow phenomenon by considering unit discharge or head above the weir crest. Figure 3.4, which represents Q = fn (headwater elevation, tailwater elevation), is divided into two zones. These indicate the conditions under which the flow over the weir is critical or in a state of submergence. By inspection, it becomes obvious that for the majority of cases the weir would be submerged; however, the most probable situation (low tailwater due to low flow in the Peace-Slave, and a moderate discharge from Lake Athabasca) would likely result in a critical flow condition.

F 106



COMPARISON OF VARIATIONS OF PARTIAL ROCK WEIR

FIGURE 3.3

TABLE 3.1

RESULTS OF TEST SERIES V

DISCHARGE (cfs x 10^{-3})	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
15	688.4	688	
	686.5	686	
	684.6	684	
	682.6	682	
	680.8	680	
	679.3	678	
	677.9	676	
	676.9	674	
	676.2	672	
	675.7	670	
	675.6	668	
25	688.6	688	
	686.8	686	
	684.9	684	
	683.3	682	
	681.7	680	
	680.7	678	
	679.9	676	
	679.4	674	
	679.2	672	
	679.1	670	
35	687.2	686	
	685.5	684	
	684.2	682	
	683.2	680	
	682.5	678	
	682.2	677	
	682.1	676	
	681.9	675	
	681.8	674	
	681.8	673	
	681.8	672	

TABLE 3.1

RESULTS OF TEST SERIES V

DISCHARGE ($cfs \times 10^{-3}$)	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
50	689.8	688	
	688.4	686	
	687.1	684	
	686.3	682	
	685.7	680	
	685.3	678	
	685.2	677	
	685.1	676	
	685.1	675	
70	691.3	688	
	690.3	686	
	689.6	684	
	688.9	682	
	688.5	680	
	688.4	679	
	688.4	678	
	688.4	677	
100	694.0	688	Flow over crest of weir
	693.4	686	Flow over crest of weir
	693.1	684	Large amount of seepage through top layer of rock
	693.1	682	Large amount of seepage through top layer of rock
	692.9	680	Large amount of seepage through top layer of rock
	692.4	678	Flow mostly confined to constriction
	692.4	676	Flow mostly confined to constriction

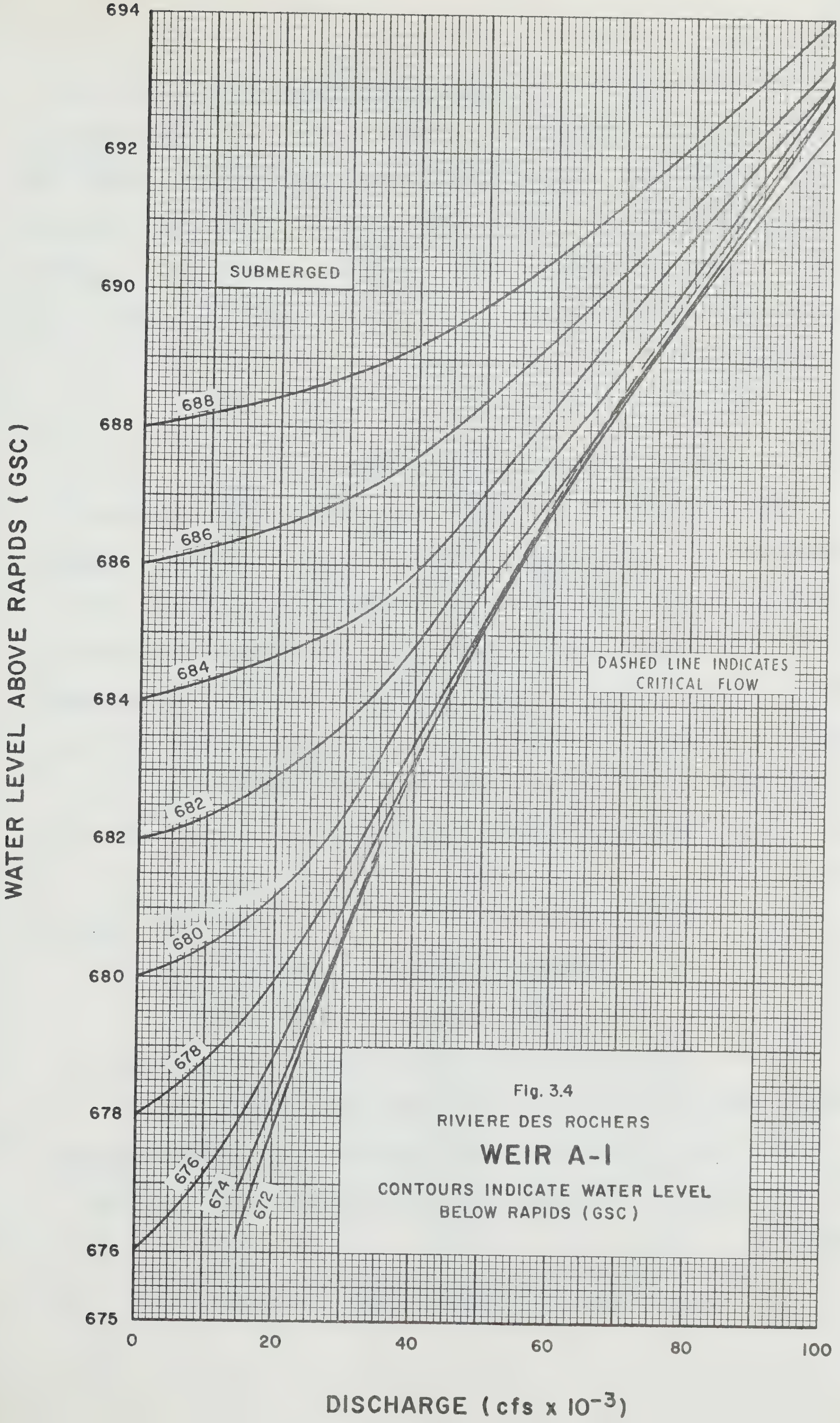


Fig. 3.4
RIVIERE DES ROCHERS
WEIR A-1
CONTOURS INDICATE WATER LEVEL BELOW RAPIDS (GSC)

No serious problems were encountered during the construction of the 550' structure, although slight erosion of the Class II core material occurred just as the final length was reached. Subsequent testing of the weir revealed that the flow was somewhat deflected towards the right bank; however, no major concentration of flow occurred at any point. Some wave action was evident at a distance of 500' to 800' downstream of the structure, on the right bank.

3.5 Test Series VI, Interpretation of Results

For Test Series VI the structure from the previous series was extended 100' to a total length of 650'. The test results are contained in Table 3.2 and the flow function is illustrated by Figure 3.5. The further constriction of the flow resulted in generally higher headwater elevations for any given discharge, as expected. However, the increased sensitivity of headwater elevation to discharge caused overbank flow in the reach upstream from the weir if the flow was much in excess of 70,000 c.f.s. The ranges in the measured quantities in Test Series VI were:

Discharge	- 15,000 to 70,000 c.f.s.
Headwater elevation	- 684.0' to 695.6'
Tailwater elevation	- 674' to 688'

As erosion problems were anticipated for the 100' extension, Class III material was used to construct the core. Despite this precaution, severe erosion occurred as the nose of the weir was extended into the deep part of the channel that forms the thalweg of the rapid section.

TABLE 3.2

RESULTS OF TEST SERIES VI

DISCHARGE (cfs x 10^{-3})	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
15	689.2	688	
	687.4	686	
	686.0	684	
	684.9	682	
	684.2	678	
	684.0	676	
	684.0	674	
25	690.3	688	
	689.1	686	
	688.2	684	
	687.8	682	
	687.4	680	
	687.3	678	
	687.2	676	
35	691.5	688	
	690.7	686	
	690.2	684	
	689.9	682	
	689.9	680	
	689.9	678	
	689.8	676	
	689.7	674	
	689.6	673	
	689.6	672	
50	693.6	688	
	693.3	686	
	693.1	684	
	693.0	682	
	692.9	680	
	692.9	678	
15	684.3	680	

TABLE 3.2

RESULTS OF TEST SERIES VI

DISCHARGE ($cfs \times 10^{-3}$)	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
70	695.6	688	Flow over crest of weir
	695.5	686	Flow over crest of weir
	695.4	684	Flow over crest of weir
	695.4	682	Flow over crest of weir
15	684.4	676	Impermeable cover on u/s face of weir
25	688.0	680	Impermeable cover on u/s face of weir
35	691.0	682	Impermeable cover on u/s face of weir

TABLE 3.3

RESULTS OF TEST SERIES VII

15	688.7	688
	686.8	686
	684.9	684
	683.2	682
	681.7	680
	681.0	678
	680.6	676
	680.5	674
	680.4	672
25	689.0	688
	687.2	686
	685.6	684
	684.2	682
	683.5	680
	683.2	678
	683.1	676
	683.0	674

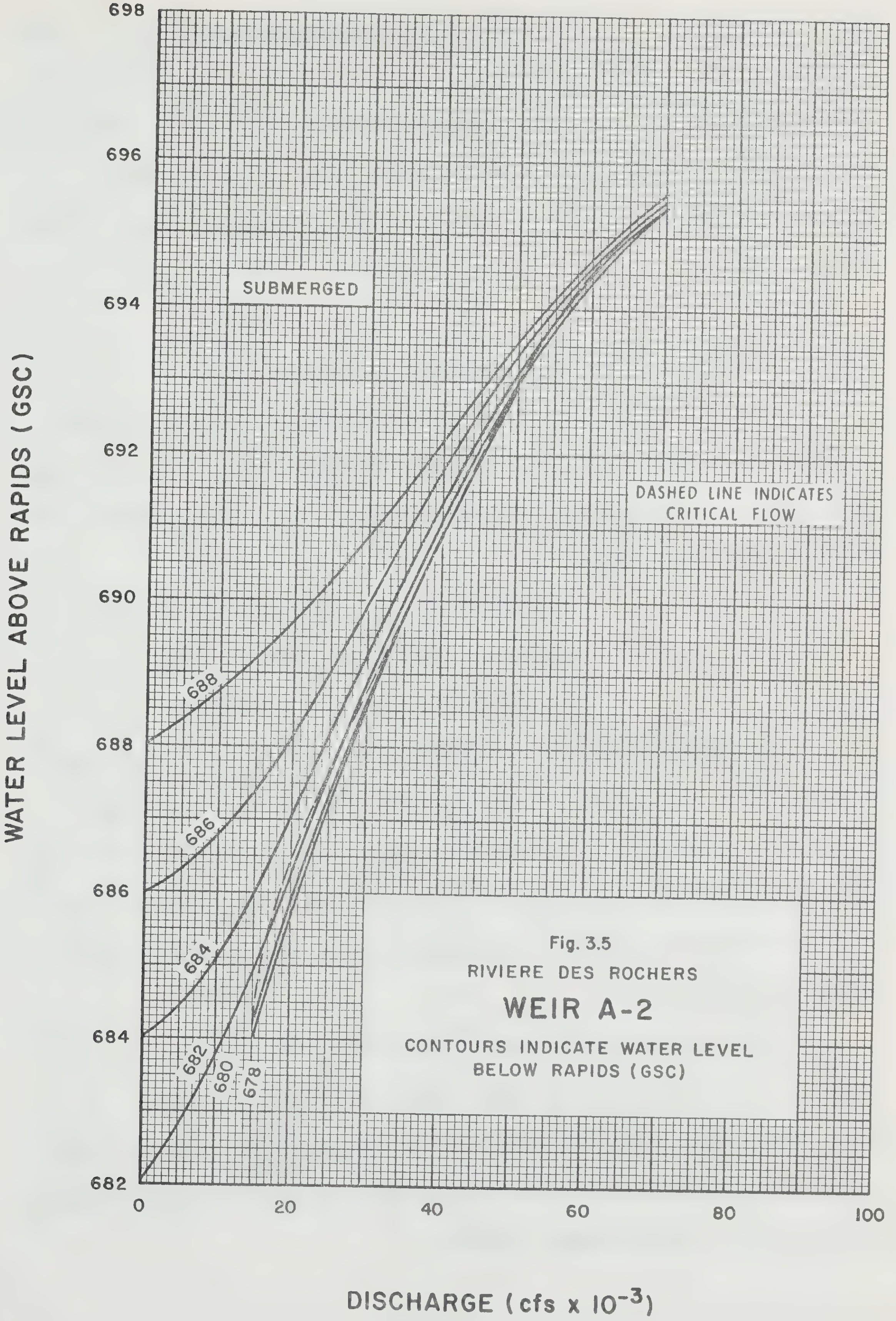


Fig. 3.5
RIVIERE DES ROCHERS
WEIR A-2
CONTOURS INDICATE WATER LEVEL
BELOW RAPIDS (GSC)

The transported particles rolled downstream on the bed to form a large "tongue" which is visible in Figures A-19 and A-20. Once the "tongue" had formed, the erosive attack was noticeably lessened and no difficulty was encountered during the subsequent placement of rip-rap (see Figures A-21 and A-22). No further instability became evident during the test series.

3.6 Test Series VII, Interpretation of Results

Test Series VII consisted of the construction and evaluation of a 500' weir from the right bank. The test data form Table 3.3 and the resulting flow function is shown by Figure 3.6. The ranges in the measured quantities were:

Discharge - 15,000 cfs to 100,000 cfs

Headwater elevation - 680.4' to 695.7'

Tailwater elevation - 672' to 690'

By comparison of the solution curves of Figure 3.6 with those of Figure 3.4, it becomes obvious that the sensitivity of headwater elevation to discharge is greater for the weir of Test Series VII than for the weir of Test Series V. In fact, overbank flow (in the reach upstream from the structure) seemed imminent at any discharge much in excess of 100,000 c.f.s.

As no problems arose during construction of the weir for this series of tests, the core was completed with Class II material. A small amount of erosion occurred, due to the existence of small eddies around local irregularities in the bed, but this did not result in any instability during subsequent testing.

TABLE 3.3

RESULTS OF TEST SERIES VII

DISCHARGE (cfs $x10^{-3}$)	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
35	689.5	688	
	687.8	686	
	686.5	684	
	685.7	682	
	685.3	680	
	685.2	678	
	685.2	676	
50	690.4	688	
	689.3	686	
	688.5	684	
	688.1	682	
	687.9	680	
	687.8	678	
	687.8	676	
70	692.2	688	
	691.5	686	
	691.1	684	
	691.1	682	
100	695.7	690	Flow over crest of weir
	695.3	688	
	695.0	686	
	694.7	684	
	694.7	682	

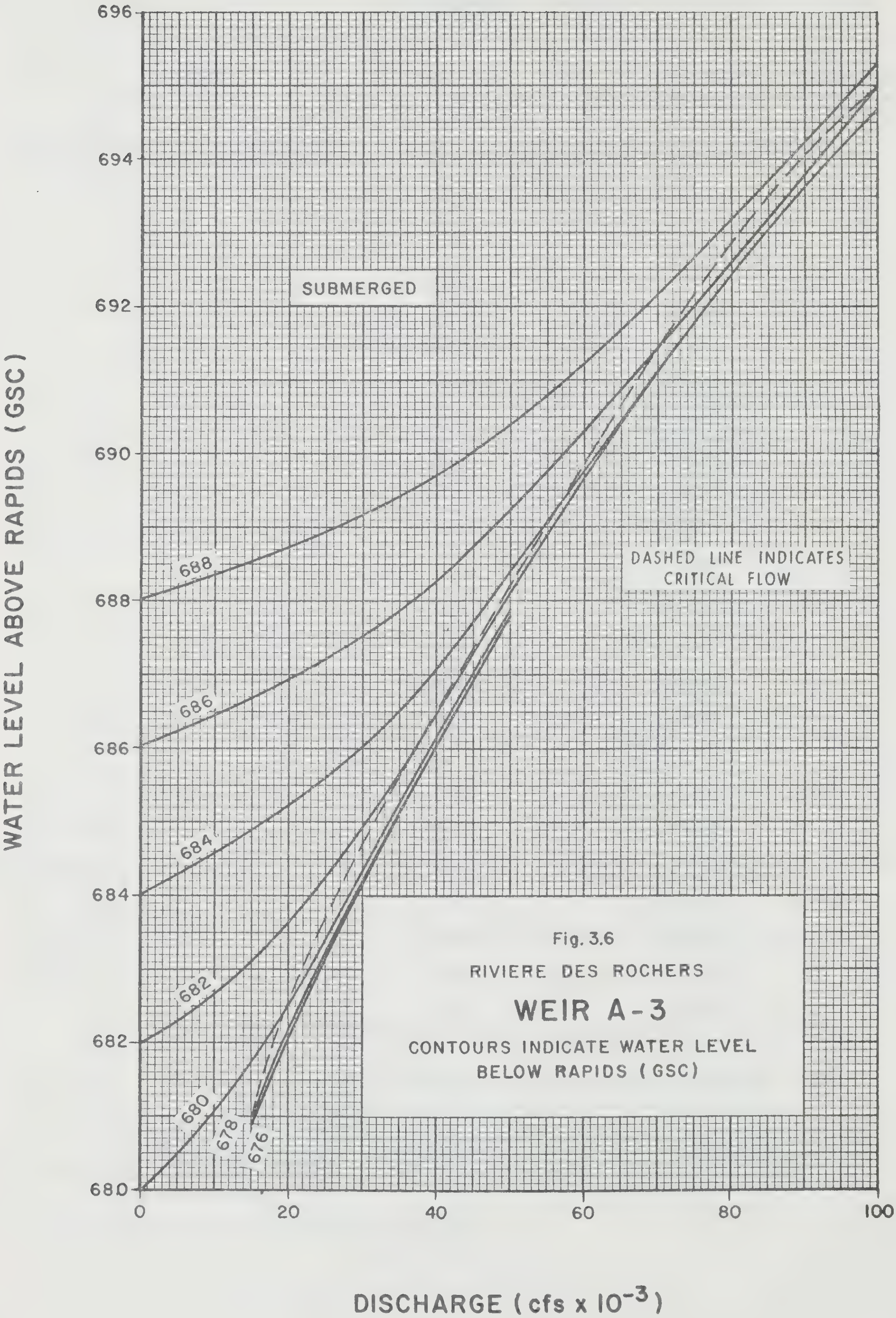


Fig. 3.6
RIVIERE DES ROCHERS
WEIR A-3
CONTOURS INDICATE WATER LEVEL BELOW RAPIDS (GSC)

3.7 Test Series VIII, Interpretation of Results

The structure from the preceding test series was extended 50' with Class II material to a total length of 550'. No stability problems were encountered during construction or testing. However, some minor wave action against the left bank was evident at a distance of approximately 1500' downstream from the weir.

The test data are contained in Table 3.4 and Figure 3.7 provides their graphical analysis. The curves show that for a given discharge-tailwater condition, the weir of Test Series VIII results in a higher headwater elevation than that for any other weir, with the exception of Test Series VI. This was verified when overbank flow occurred in the model at a discharge near 100,000 c.f.s.

3.8 Velocity Measurements

In order that the feasibility of navigation past the weir might be determined, the velocities of flow through the notch were measured. The velocities, which were measured by means of a miniature velocity probe, were the means (in the vertical) on the channel centerline. Table 3.5 contains the maximum velocities (mean in the vertical) of flow through the notch for various test conditions. In general, the maximum velocity occurred at a distance of 200' to 300' downstream from the weir centerline.

TABLE 3.4

RESULTS OF TEST SERIES VIII

DISCHARGE ($cfs \times 10^{-3}$)	HEADWATER ELEVATION (GSC)	TAILWATER ELEVATION (GSC)	COMMENTS
15	688.7	688	
	686.8	686	
	685.1	684	
	683.3	682	
	682.1	680	
	681.4	678	
	681.2	676	
	681.2	674	
25	689.0	688	
	687.3	686	
	685.9	684	
	686.8	682	
	684.2	680	
	684.0	678	
	683.9	676	
35	689.8	688	
	688.4	686	
	687.4	684	
	686.7	682	
	686.3	680	
	686.3	678	
	686.0	676	
	686.0	674	
	686.0	673	
50	691.1	688	
	690.1	686	
	689.6	684	
	689.3	682	
	689.1	680	
	689.1	678	
70	693.2	688	
	692.7	686	
	692.4	684	
	692.3	682	
	692.2	680	

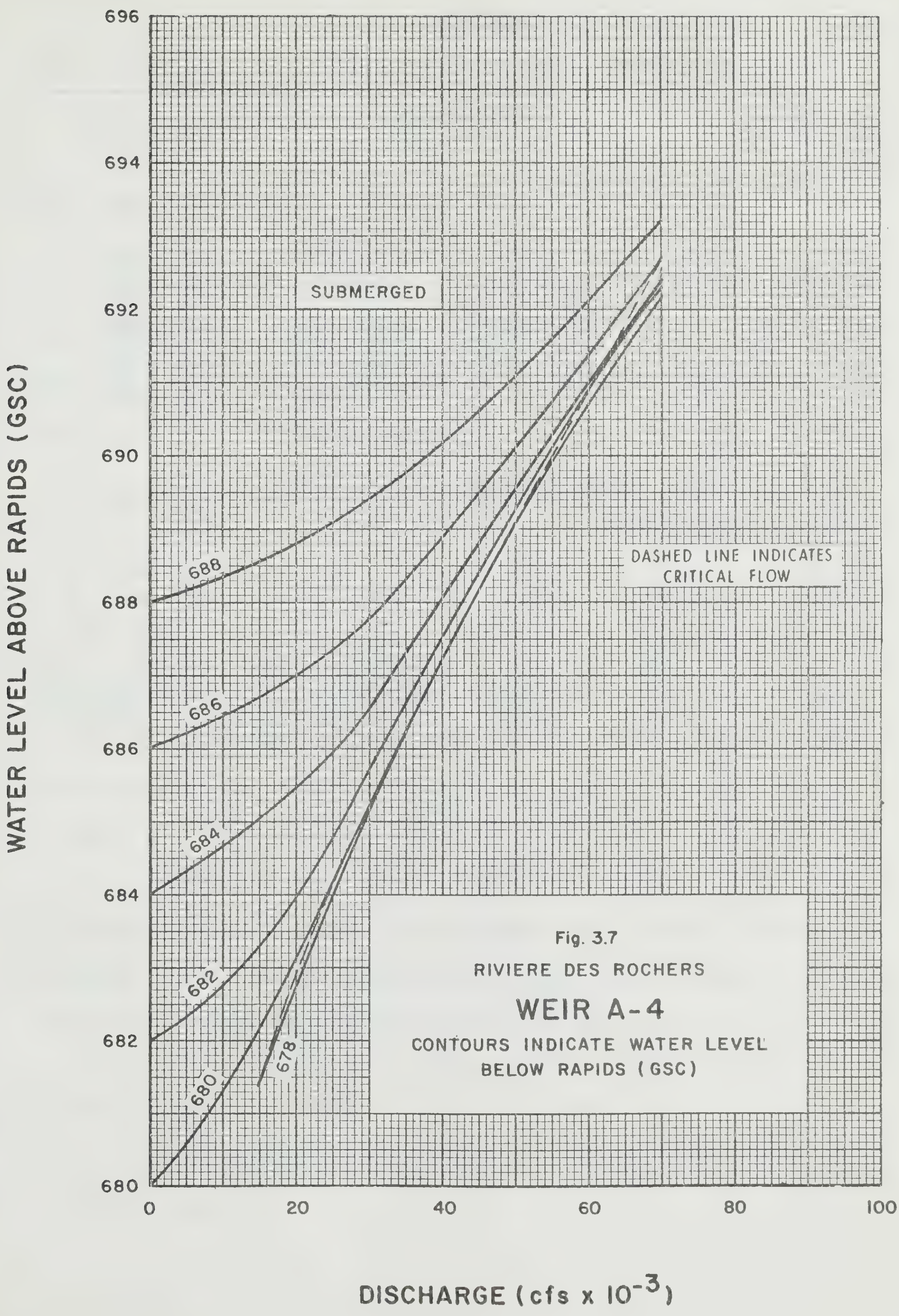


Fig. 3.7
RIVIERE DES ROCHERS
WEIR A-4
CONTOURS INDICATE WATER LEVEL BELOW RAPIDS (GSC)

TABLE 3.5

Maximum Mean (in Vertical) Velocity (ft/sec.) of Flow Through Notch

TEST SERIES	V	VI	VII	VIII
DISCHARGE (cfs)				
15,000		17.1 (674)	16.1 (674)	16.1 (674)
25,000		21.0 (676)	18.7 (674)	17.9 (676)
35,000		22.6 (673)	17.0 (676)	18.7 (674)
50,000		22.6 (678)	25.2 (676)	23.6 (678)
70,000			20.3 (682)	27.6 (680)
100,000			26.9 (682)	

Numbers in parentheses indicate tailwater elevation during velocity measurement.

3.9 Conclusions

The relations which describe the behaviour of flow through four variations of the partial rock weir are shown by Figures 3.4 to 3.7.

No difficulty is anticipated in the construction of any of the weirs except that of Test Series VI (built from left bank to a length of 650'). This variation of the partial rock weir would result in a considerable increase in the volume of core material over the amount required for the original design shape, because of the loss of material (due to erosion) during the construction of the last 100'.

CHAPTER IV

Conclusions

4.1 Backwater Effect

If we take one particular set of flow conditions and compare the resultant upstream water surface level produced by each of the structures modelled, it will provide some idea of the relative effectiveness of them to act as a water-level control.

Test Series		Discharge	Tailwater Elevation	Upstream Water Level
1	Rock Weir (25' high)	70,000	682.0	686.7
2	Rock Weir (Impermeable Core)	70,000	682.0	687.5
4	Rock Weir (10' high)	70,000	682.0	687.8
5	Partial Weir (from left bank)	70,000	682.0	688.5
6	Partial Weir (from left bank)	70,000	682.0	694.5
7	Partial Weir (from right bank)	70,000	682.0	691.2
8	Partial Weir (from right bank)	70,000	682.0	692.2

The greatest backwater effect is produced by the weir in Test Series 6. However, only a maximum discharge of 70,000 c.f.s. could be put over the weir before bankfull level was attained. Whether or not one would worry about the consequences of permitting overbank flow to occur is not for us to speculate in this report.

The partial weirs all caused a greater backwater effect than that produced by the rock weirs.

The most desirable design appears to be a partial weir as tested in Test Series 5.

4.2 Embankment Stability

It appears that the rock sizes, and method of construction specified for the rock weir is satisfactory. None of the tests during practical conditions of outflow produced any significant instability in the structure.

Testing during Test Series 6 (partial weir) indicated that either the rock material should be increased in size during construction of the last fifty feet or a certain percentage of rock volume over and above that required for the design section, would be required to compensate for transport of dumped rock downstream during construction.

4.3 Navigation

Construction of a rock weir would eliminate any future use of the channel for navigation. Also it appears that velocities through the notch of a partial weir would be in excess of 15 ft./sec., probably making it impossible for barge traffic to pass through.

LIST OF REFERENCES

1. "Athabasca Delta Project Report No. 1," Alberta Water Resources Division, Department of the Environment, September, 1970.

2. "A Hydraulic Investigation of Through and Overflow Rockfill Dams", The British Hydromechanics Research Association, Linford, A., Saunders, D. H., March, 1967.

3. "A Review of Literature on the Construction of Rockfill Dams by Dumping Stones in Running Water", Linford, A., March, 1967.

4. "Open Channel Flow", Henderson, F. M., Macmillan, 1966.

APPENDIX A

FIGURE A-1

Test series #1.
25' high wier before start of testing.

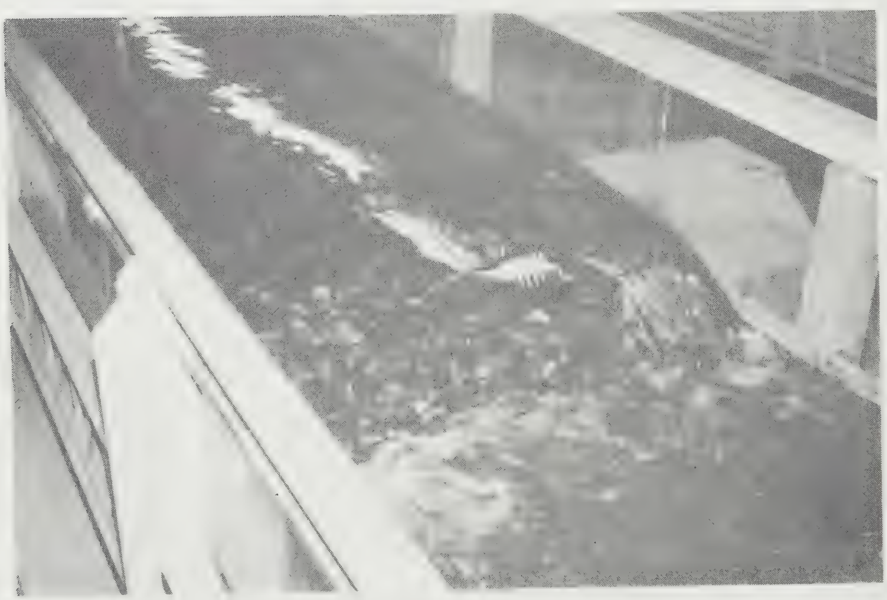


FIGURE A-2

Test series #3. (reverse flow)
Q = 187.5 cfs/ft. width.
Headwater elevation = 692.3'.
Tailwater elevation = 678'.

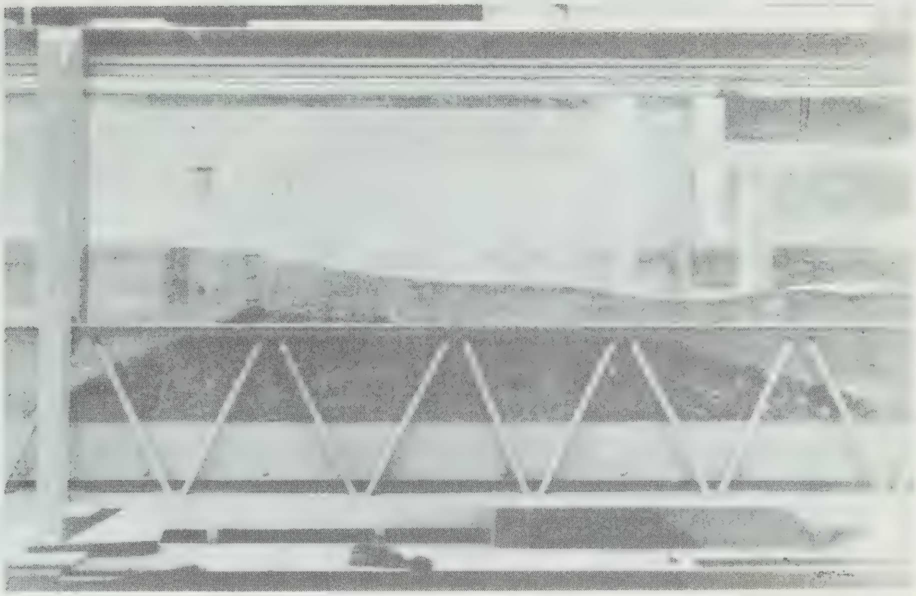


FIGURE A-3

Test series #1. (normal flow)
Q = 250 cfs/ft. width.
Headwater elevation = 686'.
Tailwater elevation = 696'.

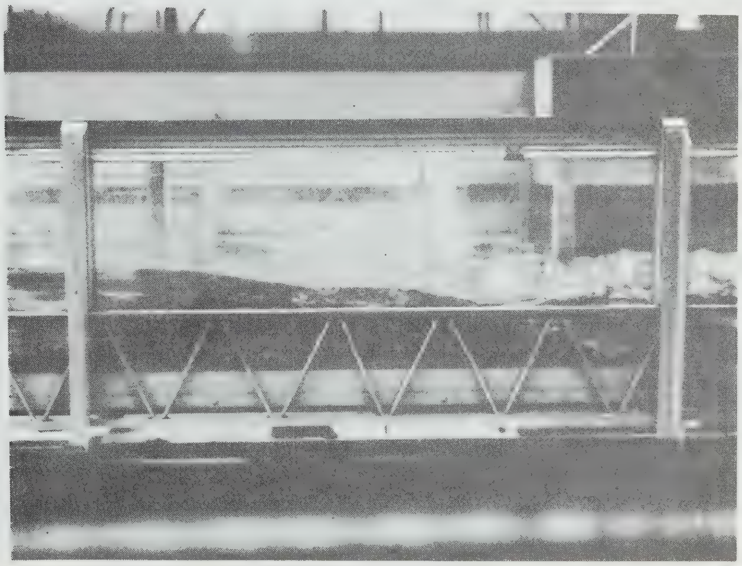


FIGURE A-4

Test series #1. (normal flow)
Q = 130 cfs/ft. width.
Headwater elevation = 689.4'.
Tailwater elevation = 678'.

FIGURE A-5

Test series #1. (normal flow)
Q = 250 cfs/ft. width.
Headwater elevation = 686'.
Tailwater elevation = 696'.

FIGURE A-6

Test series #1. (normal flow)
Q = 130 cfs/ft. width.
Headwater elevation = 689.4'.
Tailwater elevation = 678'.

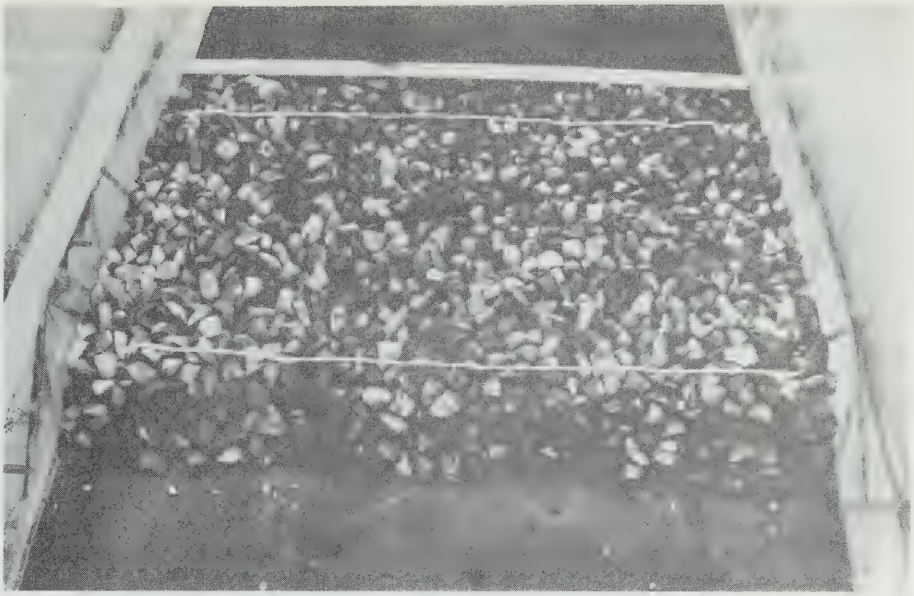


FIGURE A-7

Test series #4.
10' high wier before start of testing.

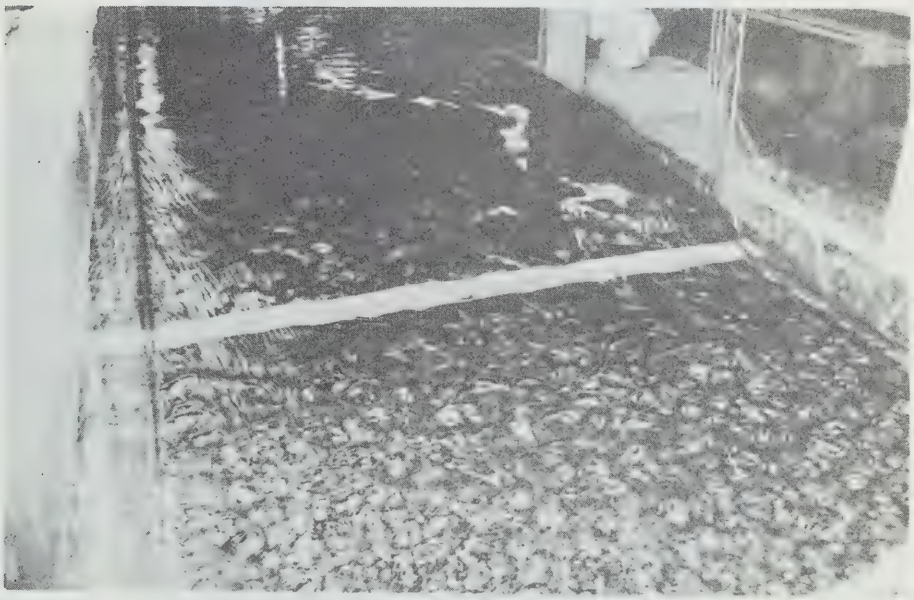


FIGURE A-8

Test Series #4.
Q = 187.5 cfs/ft. width.
Headwater elevation = 693.6'.
Tailwater elevation = 674.5'.

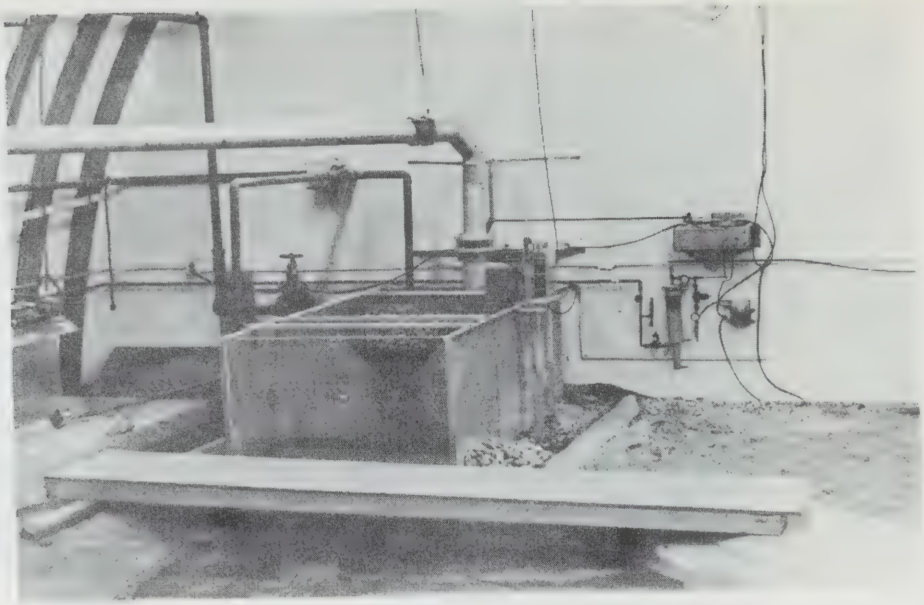


FIGURE A-9

Headtank and sharp-crested triangular weir

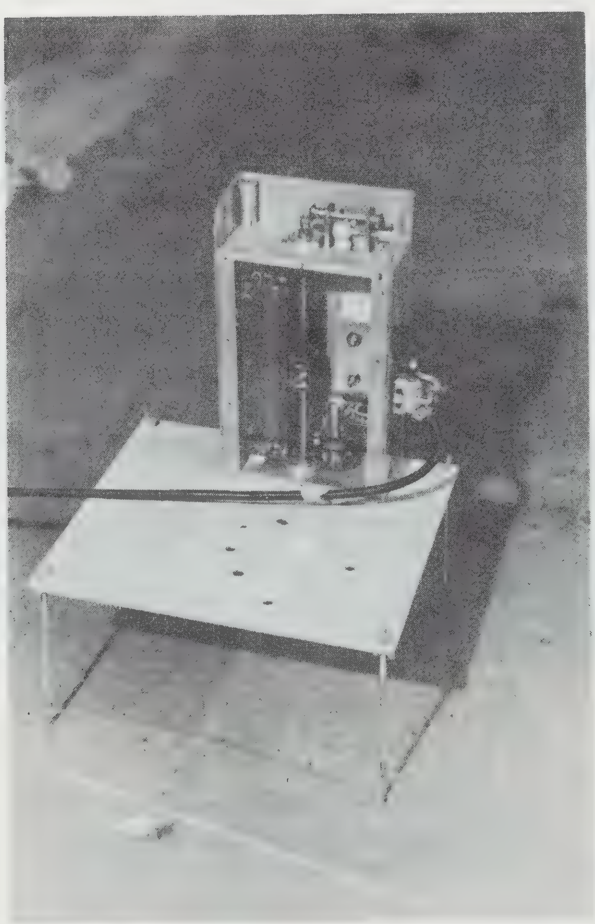


FIGURE A-10

Headwater elevation sensor

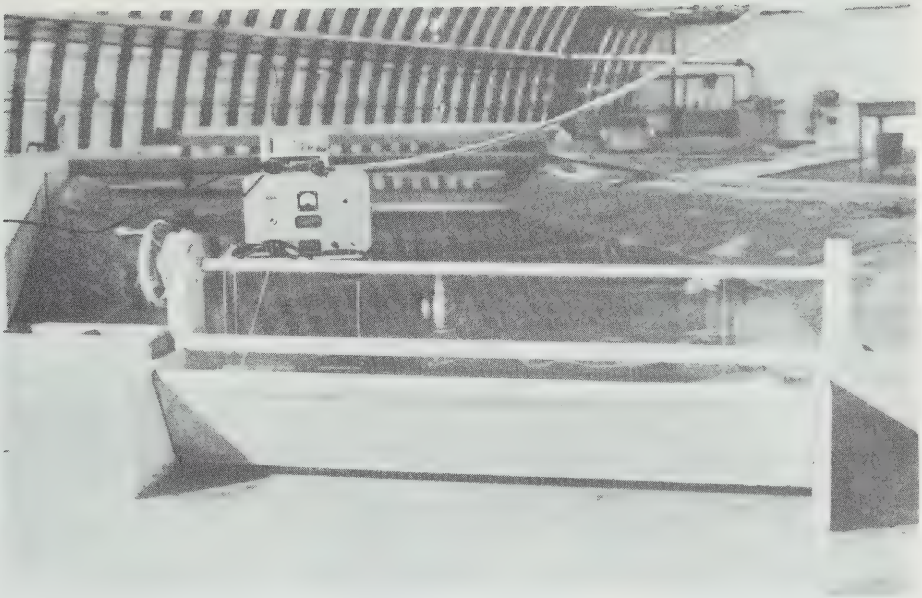


FIGURE A-11

Tailgate and tailwater elevation sensor

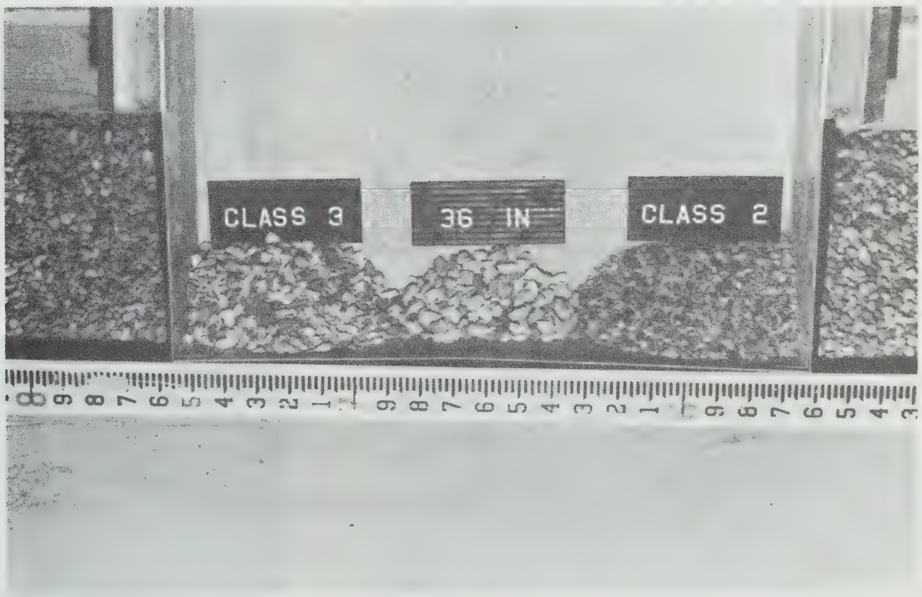


FIGURE A-12

Material used in model of partial rock weir.

FIGURE A-13

Rapid section at construction conditions.

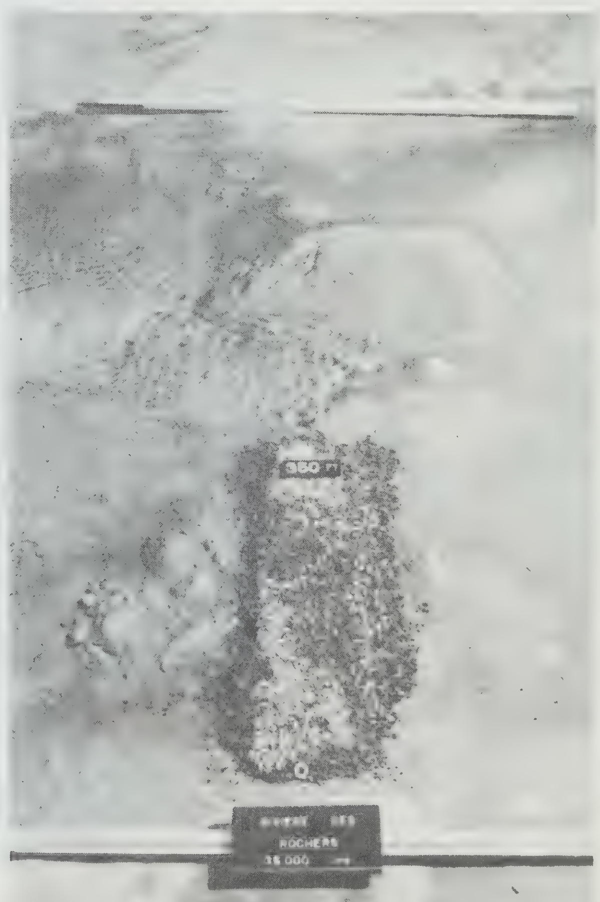


FIGURE A-14

Test series V.
Core built to length of 350'.

FIGURE A-15

Test series V.
Core built to length of 450'.

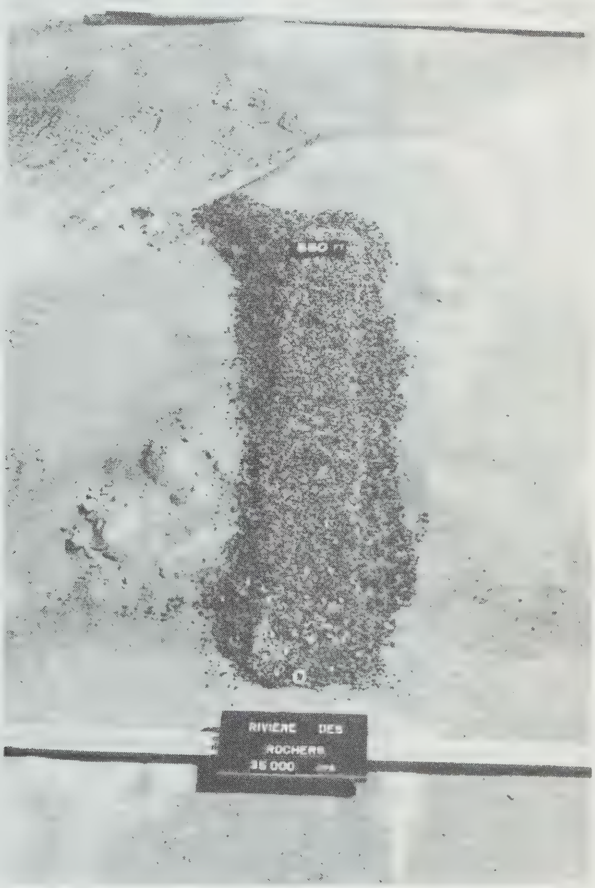


FIGURE A-16

Test series V.
Core built to length of 550'.

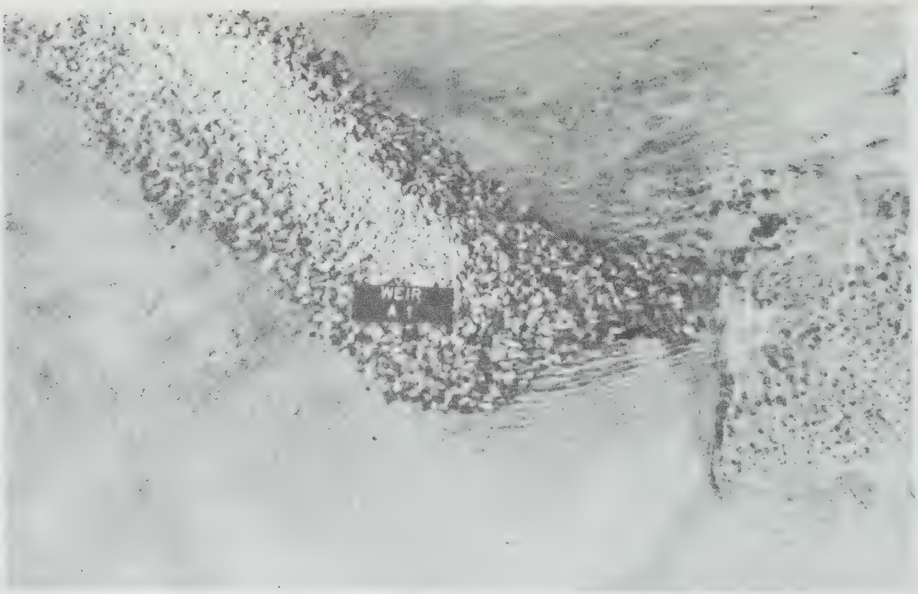


FIGURE A-17

Test Series V.
Nose of Partial Rock Weir before placement of rip-rap.

FIGURE A-18

Test Series V.
Completed Partial Rock Weir.

FIGURE A-19

Test Series VI.
Nose of Partial Rock Weir showing erosion of core material.

FIGURE A-20

Test Series VI
Nose of Partial Rock Weir showing erosion of core material.

FIGURE A-21

Test Series VI.
Nose of Partial Rock Weir after placement of rip-rap.

FIGURE A-22

Test Series VI.
Nose of Partial Rock Weir after placement of rip-rap.

SECTION G

SECTION G

PEACE-ATHABASCA DELTA PROJECT

ICE DAM PROJECT

FORT CHIPEWYAN, ALBERTA

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MAY, 1972

ICE DAM

PEACE-ATHABASCA DELTA

Chapter

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ICE DAM

PEACE-ATHABASCA DELTA

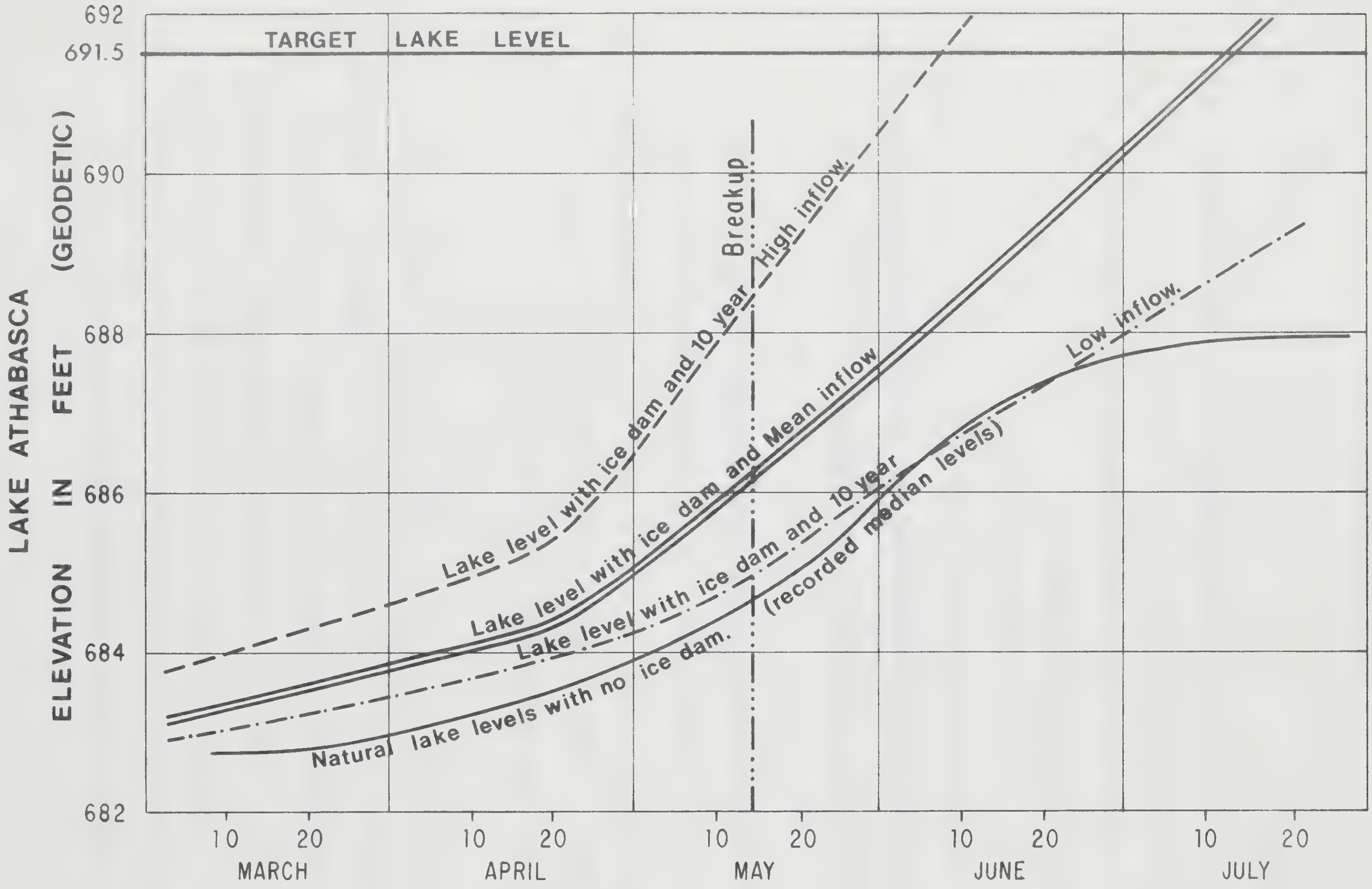
I. INTRODUCTION

The natural flood conditions on the Delta can be approximated by a summer flood to elevation 691.5 about once every five years. This could be accomplished by a temporary dam located on Rivière des Rochers, the major outlet of Lake Athabasca.

Fig. 1 shows the Lake Athabasca levels which could be expected during high, average, and low inflow years with Rivière des Rochers, temporarily dammed from early winter until summer.

This indicates that the temporary dam would be required to remain in place until mid-June in a wet year, mid-July in an average year, and about early August in a dry year, in order to bring the lake to the desired level. The most economical temporary structure capable of meeting this requirement appears to be an ice dam.

Much of the preliminary research work required for construction of an ice dam has been done in Canada, beginning with MacLaughlin (1924) and Barnes (1928) on the St. Lawrence River and more recently by Kivisild (1959), Michel (1965) and many others. The early work was concerned with the mechanics of ice formation and the removal of ice jams. The recent work has dealt with the detailed mechanics of ice cover formation on rivers, and hanging ice dams associated with jamming.



LAKE ATHABASCA LEVELS WITH RIVIÈRE DES ROCHERS DAMMED

FROM JAN. 1 UNTIL TARGET LEVEL ACHIEVED

FIGURE 1

Williams (1959)* working at the National Research Council Laboratories has studied the heat transfer and rates of ice formation in both ice covered rivers and in open water. Limited data on the freezing rates of water pumped on top of ice is available from ice bridge building experience. Balsenga (1968), with the U.S. Army Corps of Engineers, has compiled an extensive review of experience with river ice jams from the point of view of their prevention or removal.

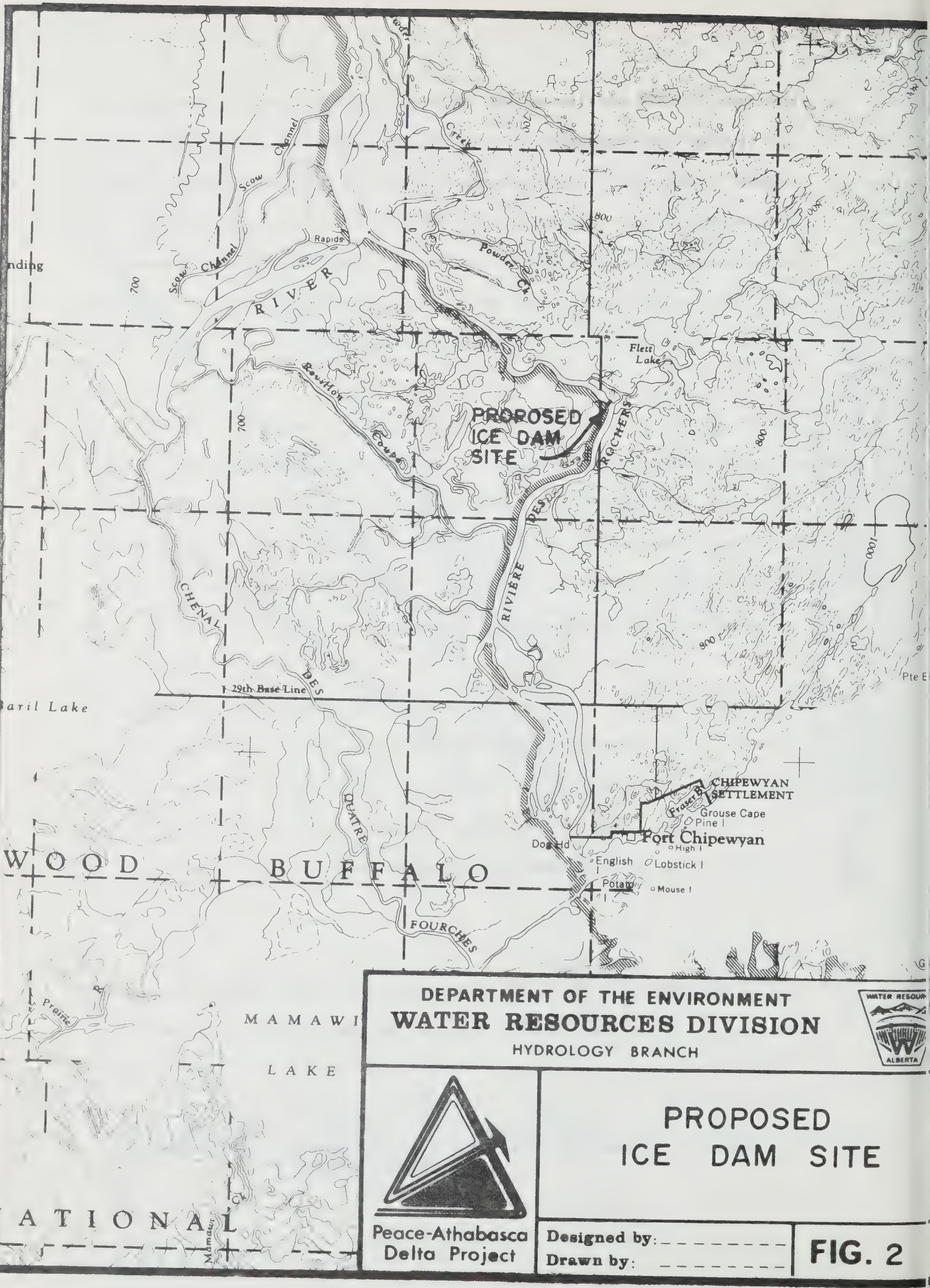
The broken ice and water mass of an ice jam can be consolidated by freezing with the use of cryopiles. Some studies on cryopiles, which are metal pipes containing a heat transfer liquid, installed vertically with about one-half their length exposed to the atmosphere, have been described by Hoffman* and Culbertson (1970). These studies were done in the Arctic sea off Point Barrow, Alaska.

The Present concept is to dam the Rivière des Rochers by creating an artificial ice jam and to build up and consolidate part of this jam with the use of cryopiles to form a solid block of ice frozen to the river bed. This ice dam would then be preserved in place until the required flood level of Lake Athabasca has been reached.

II. THE SITE

The site selected is at Little Rapids on Rivière des Rochers as shown in Fig. 2. This is the only known site on the Rivière des Rochers

* Comments or summaries from these authors are given in Appendix B.



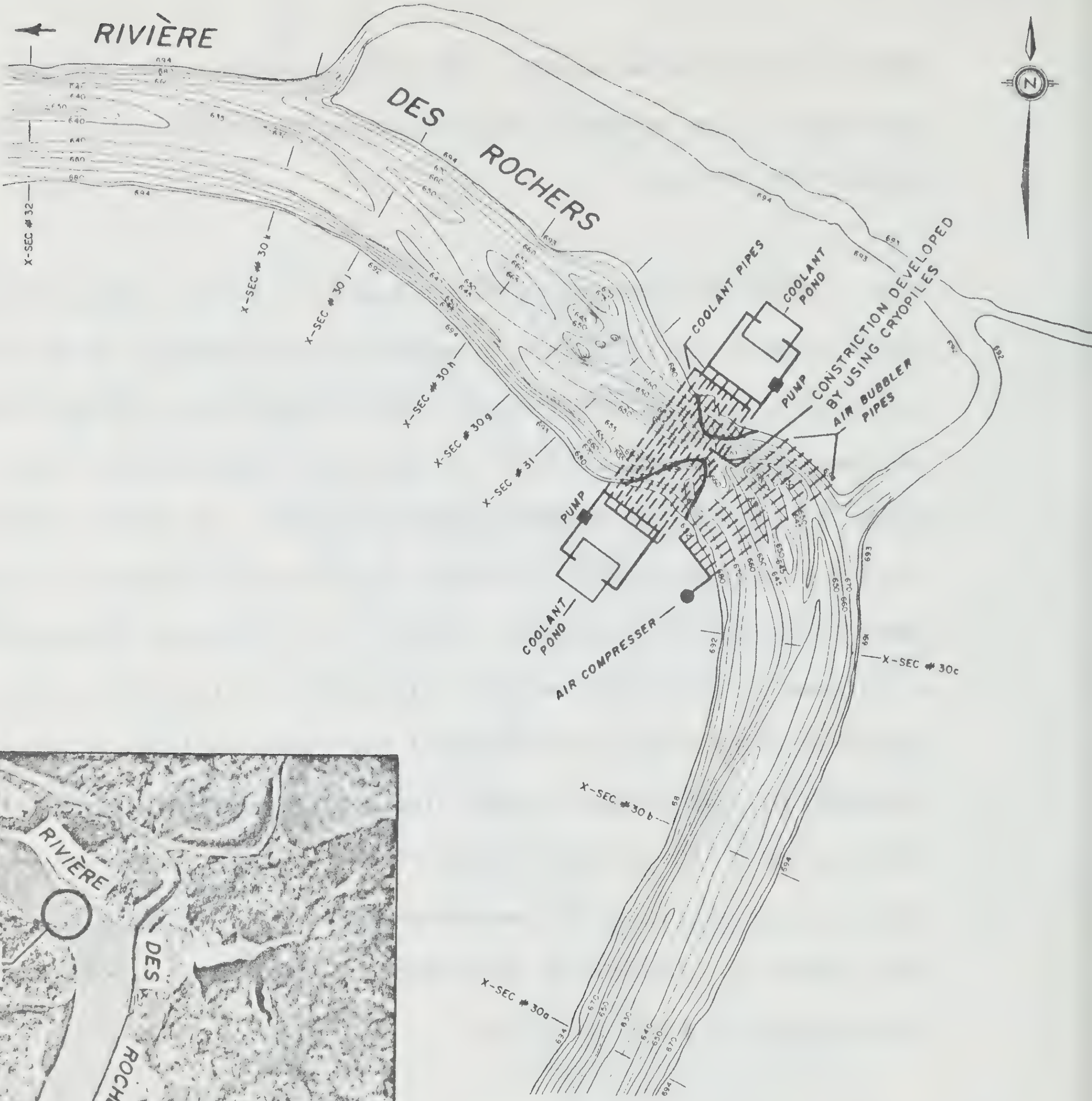
PROPOSED ICE DAM SITE
RIVER
Scow Channel
Rapids
Powder Ck
Creek
Flett Lake
Revillon Coupé
RIVIÈRE DES ROCHERS
CHENAL DES QUATRE FOURCHES
29th Base Line
Baril Lake
CHIPEWYAN SETTLEMENT
Fraser B
Grouse Cape
Pine I
Fort Chipewyan
Dog Hd
High I
English
Lobstick I
Potato
Mouse I
WOOD BUFFALO NATIONAL
MAMAWI LAKE
Prairie
Mamawi Ck
700
800
1000
Pte
DEPARTMENT OF THE ENVIRONMENT
WATER RESOURCES DIVISION
HYDROLOGY BRANCH
ALBERTA
Peace-Athabasca Delta Project
PROPOSED ICE DAM SITE
Designed by:
Drawn by:

FIG. 2

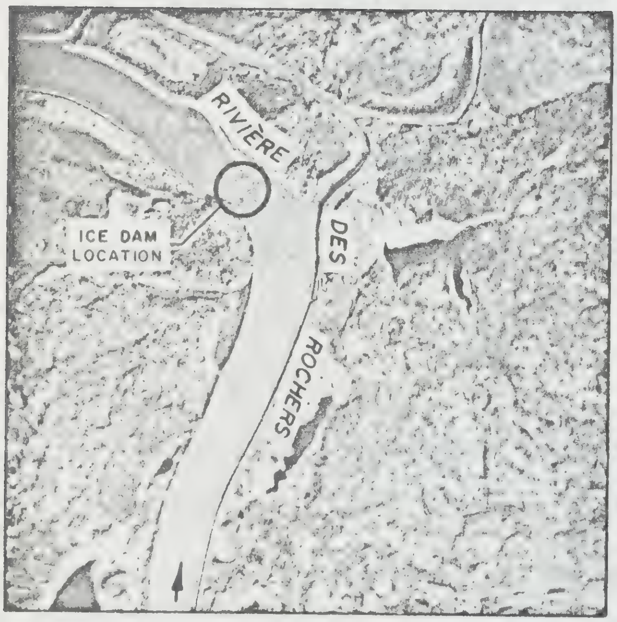
where a bedrock bottom exists. Any other location, where the bed is fine sand (0.1 mm or less), would be subject to unpredictable erosion during river closure.

Fig. 3, River Bed Contours at Little Rapids, shows the main channel is constricted to about 200 feet in width, and the bottom is about elevation 655 through the constriction. Within less than 1,000 feet upstream and downstream of the constriction, the normal river width of about 1,000 feet, and normal thalweg elevation of 640, are resumed. Water level at the Peace River for no flow in Rivière des Rochers would be about elevation 670 in December, whereas Lake Athabasca levels would be between elevation 682 and 684 at that time. Prior to river closure the water surface level downstream of the rapids would be at about elevation 673 and on the upstream side about elevation 675. Within a very few hours after closure of the river the downstream level would drop to about elevation 670 and the upstream level increase to that of Lake Athabasca. The initial difference in water level across the dam could thus be as much as 14 feet.

In order to prevent sliding of the structure when it is subjected to its ultimate difference in water level of about 21.5 feet, the ice dam should extend about 500 feet downstream of the constriction and be about 20 percent thicker than the water depth. A maximum ice thickness of from 60 to 65 feet is thus required over the thalweg near the downstream end of the dam.



ICE DAM ELEMENTS
SCALE: N.T.S.



LOCATION PLAN

PEACE - ATHABASCA DELTA PROJECT

ICE DAM CONSTRUCTION
STAGE I

FIGURE No. 3

It is vital that no seepage take place through or at the bottom of the ice dam during summer since the heat available from a prolonged flow of water, even at low velocity could cause failure. To prevent this it is necessary to freeze the entire ice mass initially, and to provide some means of removing heat which reaches the under side from deep in the earth. Heat flow due to the geothermal gradient is roughly 1.2×10^{-6} cal/cm^2 sec. or 1.6×10^{-2} BTU/ft^2 hour, Bullard (1954).

Thawing of the top of the ice can be kept to an acceptable rate by covering the structure with earth or sawdust as was done in ice houses in the past. Plastic sheet covering to prevent infiltration of rain is also desirable. The ends of the dam in contact with water must be protected from wave action by coarse gravel or broken rock.

III. RIVER CLOSURE

Freeze-up on the Rivière des Rochers occurs in late October or November. When the water temperature reaches 32°F a solid ice cover begins to form along the banks, but because of the turbulent current, water in the central channel becomes slightly supercooled and frazil ice forms. Frazil ice particles are about 75 microns in diameter and because of their small size are carried beneath the surface by turbulent eddies.

Frazil particles tend to stick together and then to rise to the surface, freezing more solidly into ice "pans" as they float along. These ice pans become more numerous and closely spaced as the weather grows colder, and as they move downstream from the lake. Finally a stage is reached where the pans cover the river surface and a shallow surface

ice jam occurs; this is generally at a bend or constriction. The initial jam at any point may fail to hold, but eventually a stable jam occurs and the cover begins to build upstream by pans arriving subsequently. Kivisild (1959) has shown that an ice cover will build upstream if the Froude number of the flow is less than about 0.08.

$$F = \frac{V}{\sqrt{gh}} \overset{>}{r} 0.08$$

where V is the mean velocity in feet/sec., h the hydraulic mean depth and g, 32.2 feet/sec.^{2}.

Detailed freeze-up observations are not regarded as necessary, but a site inspection in mid-December 1971 indicated that an ice cover begins to form at some point downstream of Little Rapids and builds upstream to within a few hundred feet of the constriction, at which point the Froude criterion is exceeded. The presence of a hanging dam at least 10 feet thick containing large pieces of ice in the centre of the river downstream of the rapids in December 1971, probably indicates that a cover did not begin to form on the upstream side of the constriction until some time after the downstream cover was complete. Open water is known to exist throughout most, if not all, of the winter from the constriction to a point a few hundred feet downstream and to have a width of about 200 feet. Plate A68 shows the open water in December 1971.

The hanging dam just downstream from the constriction is the best location for an artificial jam since a mass of ice forms there naturally and the high velocity at the constriction can be used to carry ice

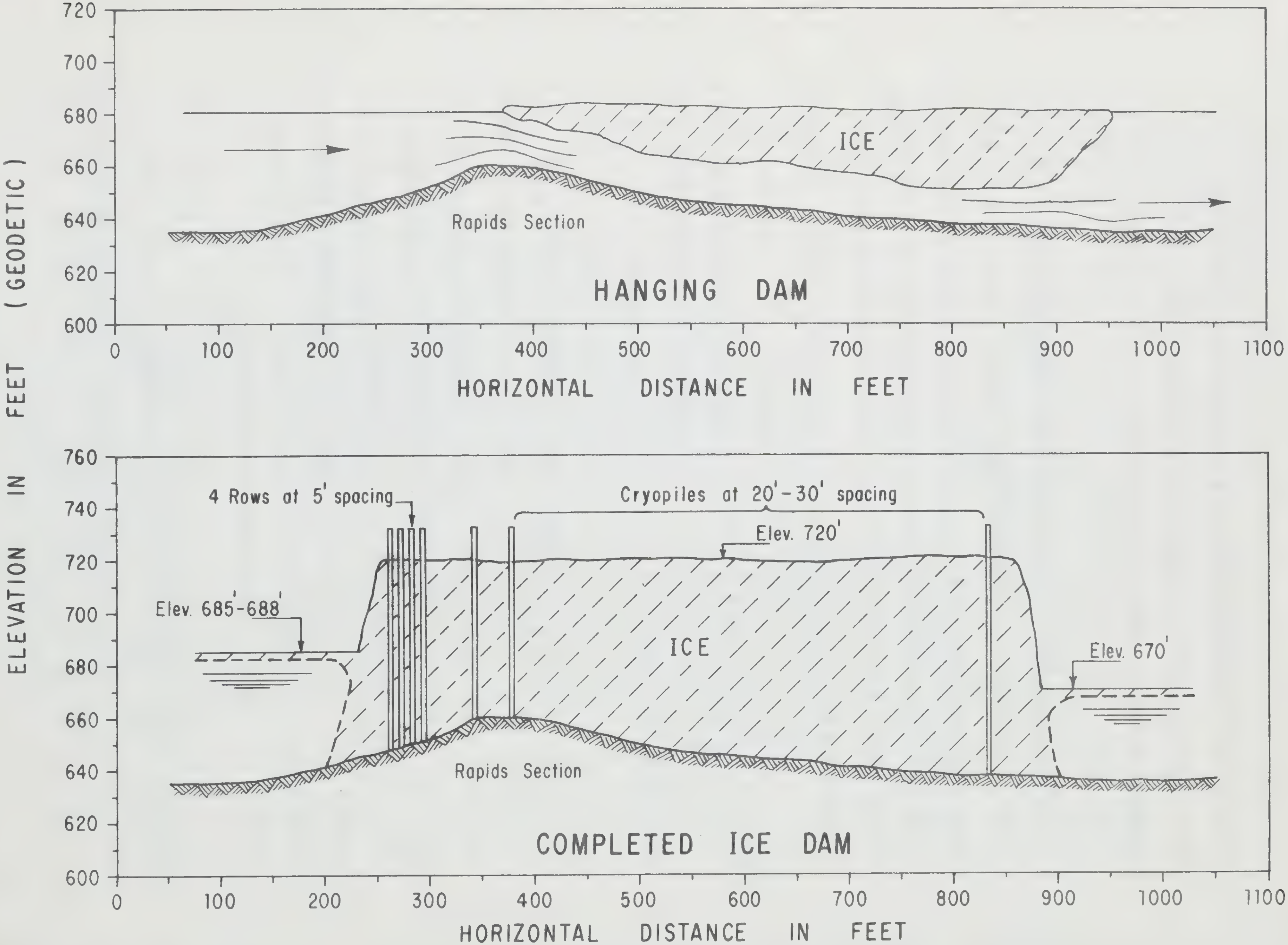
blasted free upstream under the cover to increase the depth of the hanging dam, ultimately creating a jam which closes off the river. The effort required to freeze solidly the broken mass of ice in the hanging dam is much less than that needed if no ice was present.

Initial steps toward closure of the river should begin by flooding the ice on either side of the main channel as soon as average daily temperatures reach about 15°F. When a strong cover has formed on the sides, cryopiles would be placed in the flooded area shown cross-hatched on Figure 4 and ice build-up continued as rapidly as possible by direct flooding and by sprinkling.

When the ice cover upstream from the constriction had thickened to 12 to 18 inches, blasting upstream ice to augment the naturally occurring hanging dam downstream from the throat would be started.

Model tests, reported in Appendix E of this report, carried out in a 1:100 scale model using blocks of polyethylene to represent ice indicate that the hanging dam will build up over the width of the river and will extend 500 to 800 feet downstream from the constriction. According to Kivisild (1959) the hanging dam will build downward until, at a flow of 20,000 c.f.s., an equilibrium water depth of 7 to 10 feet would exist at the downstream end of the dam as shown on Figure 4. If the flow was 40,000 c.f.s. the equilibrium depth would be about 15 feet.

The model results show smaller equilibrium depths.



Peace - Athabasca Delta Project

ICE DAM CROSS - SECTIONS

FIGURE 4

The equilibrium gradient of energy head beneath the hanging dam would be about 0.8 feet/1,000 feet for 20,000 c.f.s., so the change in water level across the rapids due to the hanging dam would be well under one foot. A smaller decrease in water level would occur downstream.

Continued slow feeding of broken ice to the hanging dam would increase its length in the downstream direction and increase the energy loss in proportion.

Model tests have shown that the rapid release of large ice pieces, of the same order of size as the opening beneath the dam would be drawn underneath, blocking the opening. Thus when the hanging dam has been slowly built to equilibrium depth using small (4 to 10 foot) ice floes, closure would be made by the sudden release of a large quantity of larger pieces.

The quantity of fine ice particles released when blasting out floes in the river above the constriction is not likely to be sufficient to fully plug the interstices in the hanging dam and in addition it is possible that the river water would be a few one-hundredths of a degree above freezing and so could cause some melting in the dam. Installation and operation of an air bubbler system upstream from the constriction would create a heat loss which would ensure slight super-cooling of the water and some frazil ice production. Williams' (1959) data for heat loss from an open water surface shows an air temperature of -20°F above open water will remove about 120 BTU/ft^2/hr. For a river flow of 20,000 c.f.s. at an initial temperature of 32.1°F it is necessary to remove

7.2×10^6 BTU/hr. An open water area of about 60,000 ft^2 would therefore be required to cool the water to the freezing point. The air bubbler systems should thus extend across the river and upstream for 60 feet per 0.1°F of water heat available. The water temperature in December is believed to be less than 32.1°F but it appears prudent to allow a safety factor of about 10 here, firstly to overcome water heat and secondly to produce frazil ice in abundance. For an air bubbler system covering 600 feet of 1,000 feet wide river, the mean December temperature of -2°F (-19°C) would remove about 72×10^6 BTU/hr., sufficient to cool the water 0.1°F and to produce 450,000 lbs. of frazil ice per hour, with a volume of about 7,800 cubic feet.

The air bubbler system would consist of weighted plastic pipes laid on the river bed during open water. The end of each pipe would be buried in the bank so that static water level was below the frost line. It would be started as soon as a firm ice cover exists, at that point and run continuously until closure.

Design of air bubblers is discussed in Proceedings of the Symposium on Air Bubbling, National Research Council, Technical Memorandum No. 70, Ottawa, 1961.

Erosion beneath the dam is to be expected in areas where a sand bed exists unless the bed is protected. It is also necessary, at least during the first trial of the ice dam, to be able to remove heat from the base of the dam should temperatures there rise to near thawing temperatures during the summer. A series of coolant pipes laid on the bed

before construction of the dam starts can be used to freeze the bed prior to closure, to help extract heat from the ice-water mass during build-up of the ice mass, and to cool the ice during summer months should this be found necessary. It is proposed that the coolant be diesel oil, kerosene or calcium chloride brine. The coolant should be stored in shallow, open surfaced ponds set well up on each river bank and should flow by gravity through the cooling pipes into collector pipes running parallel to the shoreline at about elevation 675. The coolant would be pumped from the collector pipes back into the ponds where it would be discharged through nozzles suspended above the surface in order to achieve a maximum cooling effect. In summer the ponds and collecting pipes would be disconnected so that a portable refrigeration unit could be attached to the pipes to cool the base of the dam as required.

It must be recognized that the first attempt at closure may not be successful because the downstream ice sheet may "telescope" under the hydrostatic forces involved. Telescoping, which is a horizontal compression of the hanging dam will strengthen the dam and the final closure attempt can be repeated until successful. It is advisable to build the hanging dam to equilibrium depth as early in the winter as possible. Failure on the first attempt would not be serious and success would increase the time available to build up the required ice mass.

The water surface elevation on the upstream side of the dam will increase rapidly to Lake Athabasca level within a few hours after closure and the downstream surface will fall to the level of the Peace-Rivière

des Rochers confluence in an even shorter period. The rise in level on the upstream side will force water over the ice at the upstream end of the dam and, unless an ample supply of blasted ice from upstream is available the closure might fail because of overflow.

IV. DAM CONSTRUCTION

Immediately after closure a double row of cryopiles, preferably 8 inch diameter steel pipes, 50 feet long, at 5 foot centers containing diesel oil or kerosene as a heat transfer medium should be placed across the constriction. The first cryopiles can be placed by cranes working from either bank.

A log reinforced ice bridge should be built across the jam at the constriction and used as a base for the cranes installing the remaining cryopiles.

When the upstream cryopiles are in place, a single row of longer piles should be installed in the same manner across the downstream end of the dam.

Both upstream and downstream rows of cryopiles must be left in position throughout the winter in order to get maximum cooling at these areas and to freeze the subsoil or rock to the greatest possible depths. The frozen subsoil will act as a cutoff wall, limiting under-seepage.

Build-up of ice by direct flooding, and spraying, would be started over the main body of the dam immediately at closure. Following placement

of the up and downstream cryopiles, the other cryopiles should be installed throughout the body of the dam. The cryopiles in the main dam should be placed at about 20 foot centers. The probable rate of freezing of the ice-water mass around these cryopiles is discussed in Appendix D.

Ice build-up on the surface of the dam and freezing of the ice-water mass by the cryopiles must be continued until the ice surface is at an elevation such that the thickness of ice at any point is at least 20 percent greater than the maximum elevation of a line drawn from maximum upstream water level to downstream water level. The density of the ice produced must be measured as it is built up and this used to check stability and to revise the 20 percent figure upward if necessary.

The cryopiles should be removed about the end of March. This can be done by pumping out the heat transfer fluid and melting the bond by means of a steam generator prior to lifting with a crane.

Two thermisters to measure temperature of the ice mass should be placed in cryopile holes at about 100 foot spacing throughout the dam. These should lead to wooden posts firmly embedded in the surface ice. The electrical connections should be about 6 feet above the ice.

V. PROTECTION FROM MELTING

Gravel and/or crushed rock protection up to elevation 693 on the upstream side and 685 on the downstream side should be placed during the

month of April. The blanket should be about 3 feet thick. It will probably be necessary to blast a trench through the surface ice at these points in order to place the rock.

Earth and/or sawdust from 2 to 3 feet thick should be placed over the surface of the dam. If this is frozen it should be leveled and then covered with plastic sheeting.

The thermisters should be read at weekly intervals throughout the summer and a plotted record maintained in the construction office. If the bottom temperature rises above 30°F, artificial refrigeration should be applied by means of the bottom cooling pipes.

VI. DAM REMOVAL

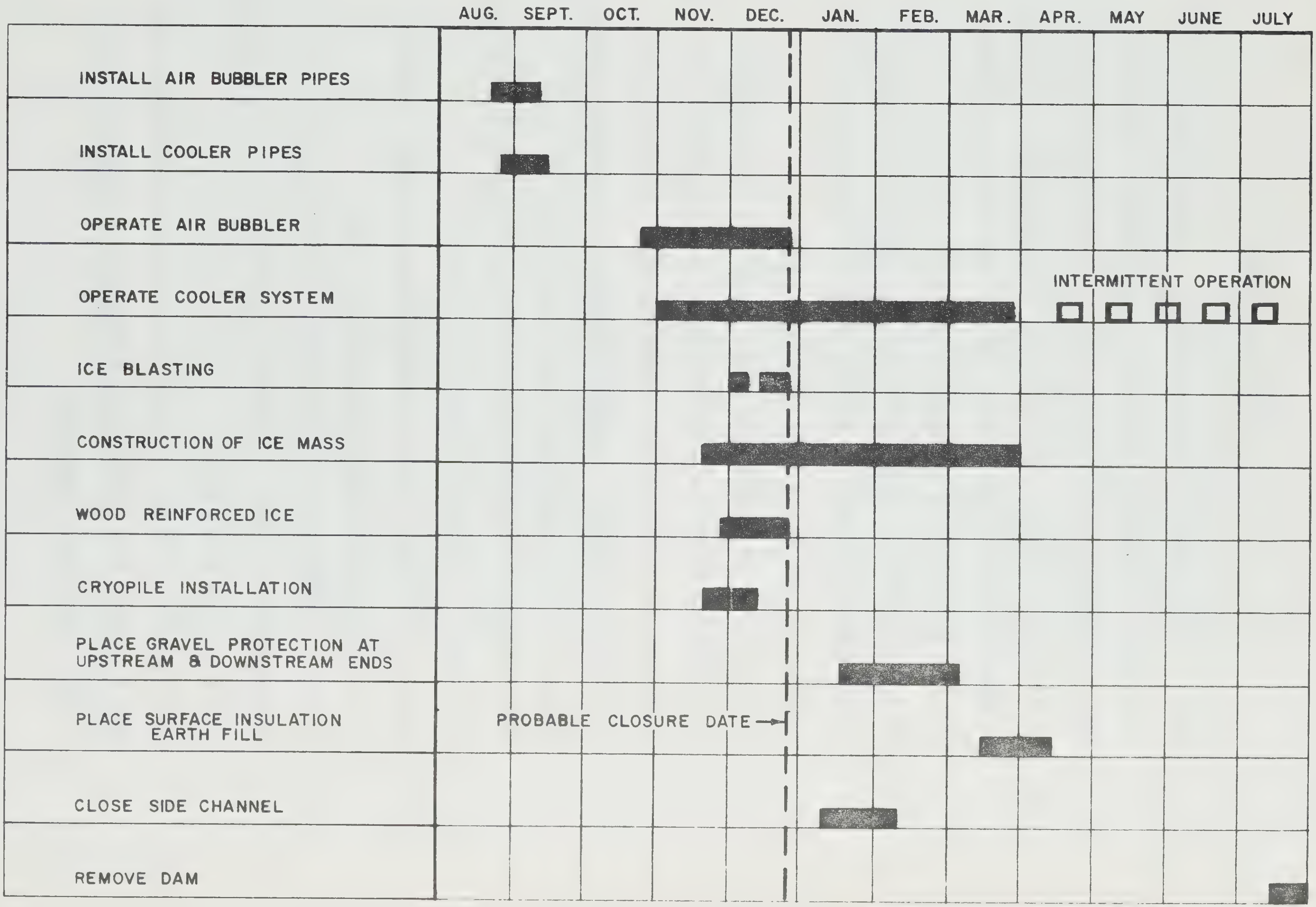
In order to prevent large blocks of floating ice, the dam should be removed by a large number of dynamite charges set deep in the structure. This would crack the mass into small pieces and allow water to seep through and complete the demolition.

VII. CONSTRUCTION SCHEDULE

Figure 5 shows the approximate construction schedule required. The dates are weather dependent during November and December.

FIG. 5

PROBABLE CONSTRUCTION SCHEDULE FOR ICE DAM
(WEATHER DEPENDENT)



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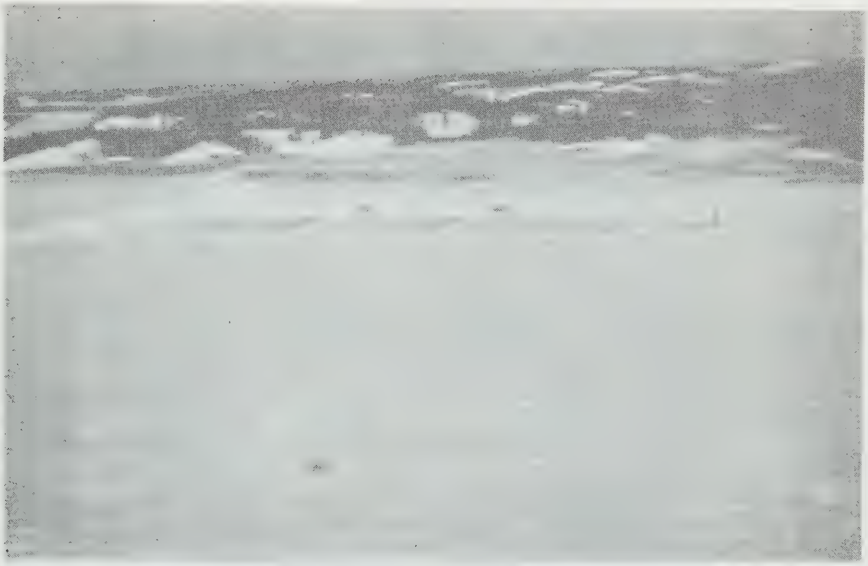
APPENDIX A

PHOTOGRAPHS

A-1 Overall view of ice making site looking upstream on Riviere des Rochers. Note the winter road crossing just downstream of site.



A-2 Overall view of site showing plots 1, 2 and 3 with cryopiles on extreme right upstream.

A-3 Ice-making experiment at Lambton Park using two 10,000 gallon tanks.

A-4 Peace-Athabasca Delta Project Camp in Fort Chipewyan used as base of operation during ice making experiment.

A-5 Electric plant used to operate flood lamps during night-time.

A-6 Grid posts (2" x 2") used to indicate depth of ice formed.
Shacks in background used to house pumps and light plant.

A-7

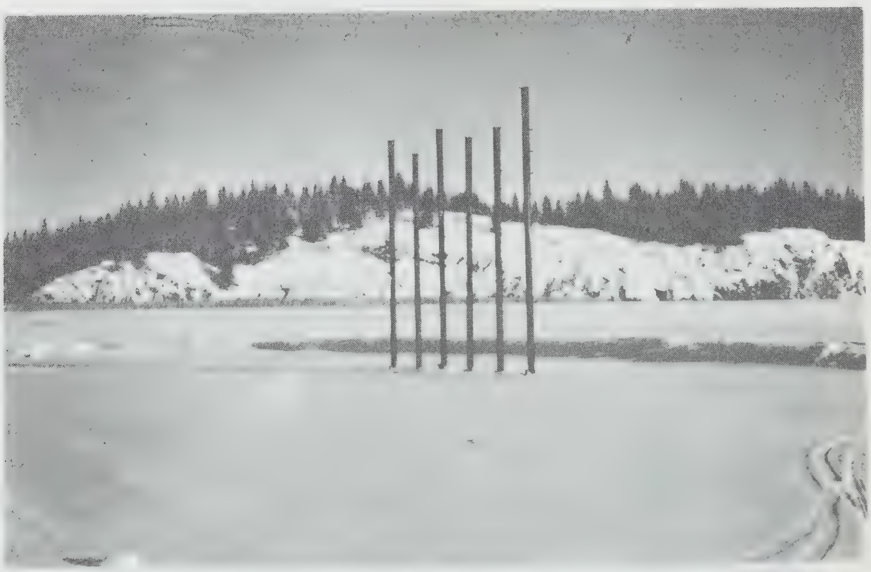
Views of cracks that developed in plots 2 and 3 during and after flooding. No cracks were observed wider than $1\frac{1}{2}''$.

A-8

A-9 Placement of 40 foot cryopile into hole (bottom left corner) in ice using helicopter. This method was abandoned after placing 2 piles because of the dangers involved.

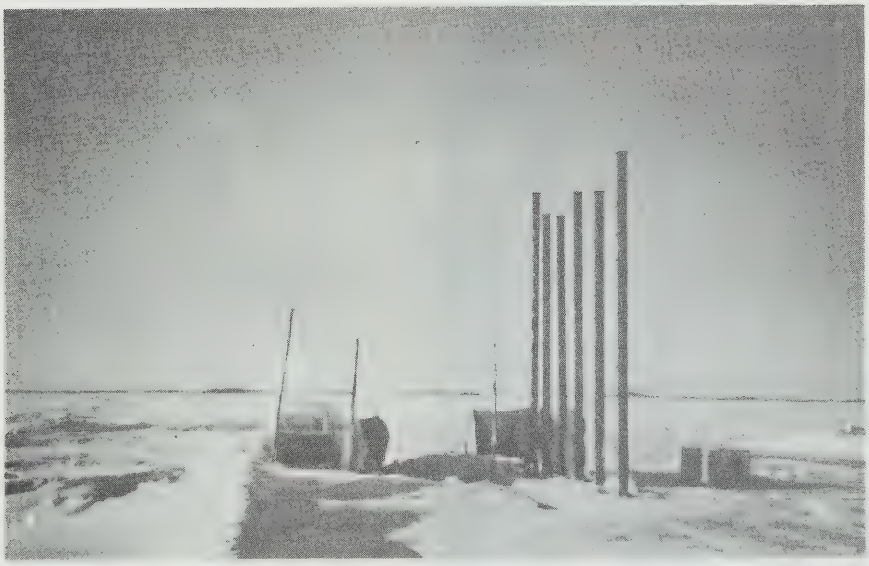
A-10 Giving signals to helicopter during placement of cryopile.

A-11 Placement of cryopiles using bin pole attachment on loan from Alberta Power.



A-12 View of six original cryopiles - placement completed February 11, 1972.

A-13 Filling cryopile 1, 2, 5 and 6 with diesel fuel from tank truck - February 11, 1972.



A-14 Preparing cryopile site with windbreaks for divers. Note freon from empty bottles on right has been bled into cryopiles 3 and 4 - February 15, 1972.

A-15

Divers preparing to swim below the ice and take measurements of cryopiles. Note that the single diaphragm regulator worn by the diver below usually froze up under water but the double diaphragm worn by the diver above did not.

A-16

A-17

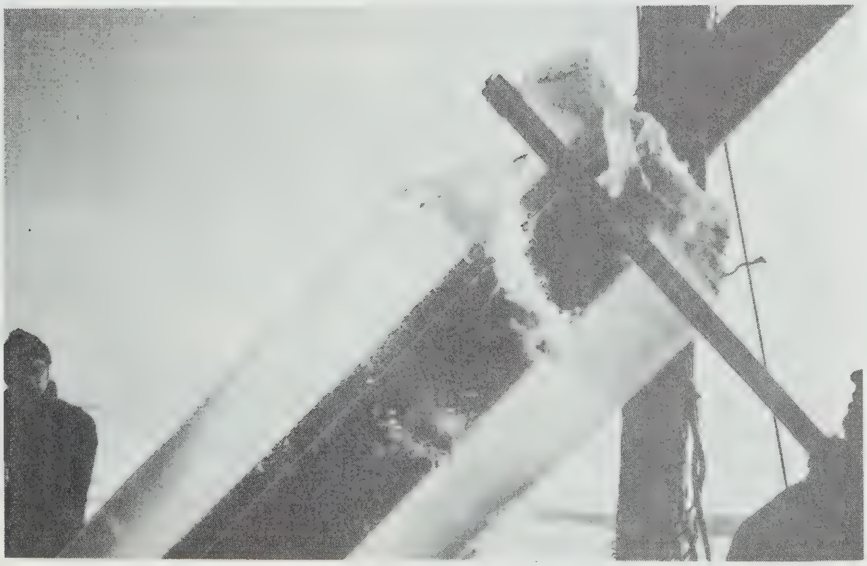
Views of divers in access hole preparing to swim below the ice to measure cryopiles.

A-18

A-19
Top measurement of cryopile #1, 2.8' diameter.

A-20 Cryopile #1 middle measurement = 2.5' diameter. Top portion has been chipped away to facilitate removal of pile.

A-21 Cryopile #2 top diameter 2.6' - Some ice near the top broken off during removal.



A-22 Cryopile #2, middle diameter 2.2'.

A-23 Cryopile #2 - bottom diameter 2.0'. Note hemisphere of frozen silt at bottom of pile.

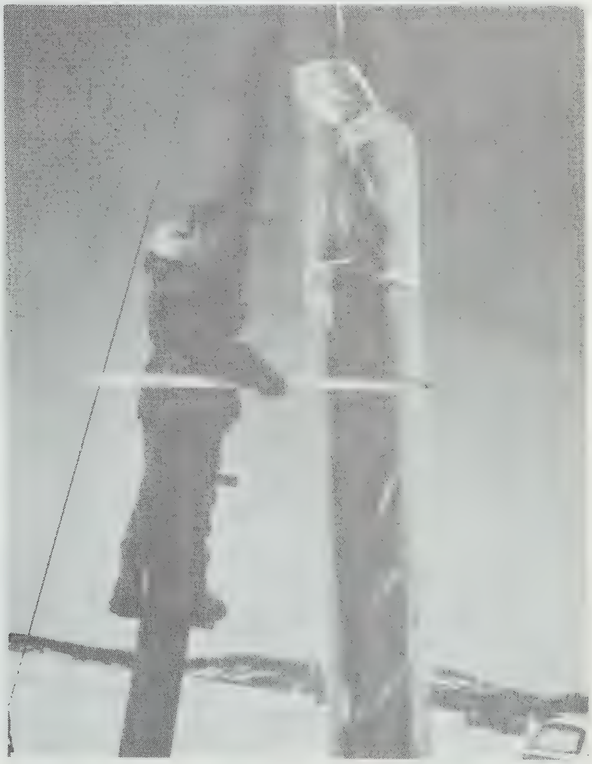
A-24 View of bottom end of cryopile #2.

A-25

Cryopile #3 showing total amount of ice remaining at time of removal. Note no ice at base of pile.

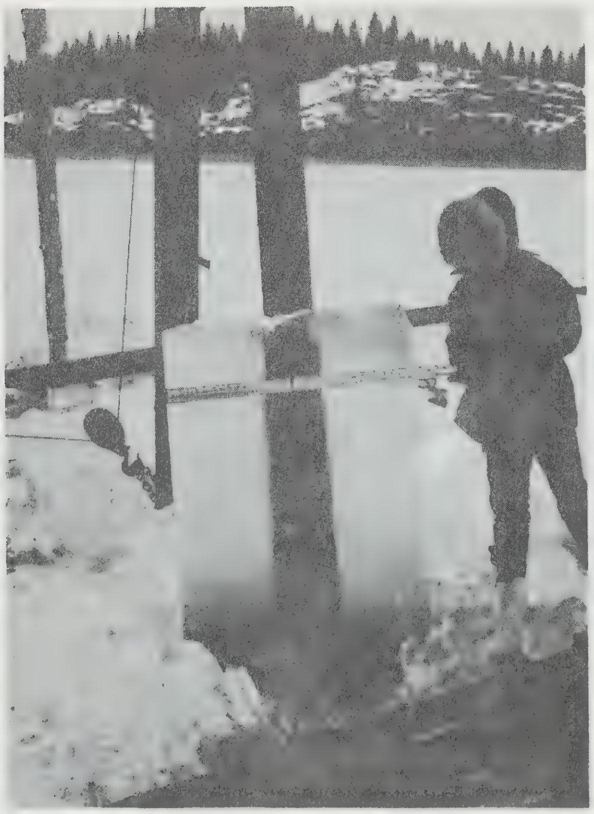
A-26

Cryopile #3 middle diameter 1.6'.



A-27

Cryopile #4 top diameter 3.5'. Note curvature at base of river ice marked by drill holes. This pile was the largest of all.

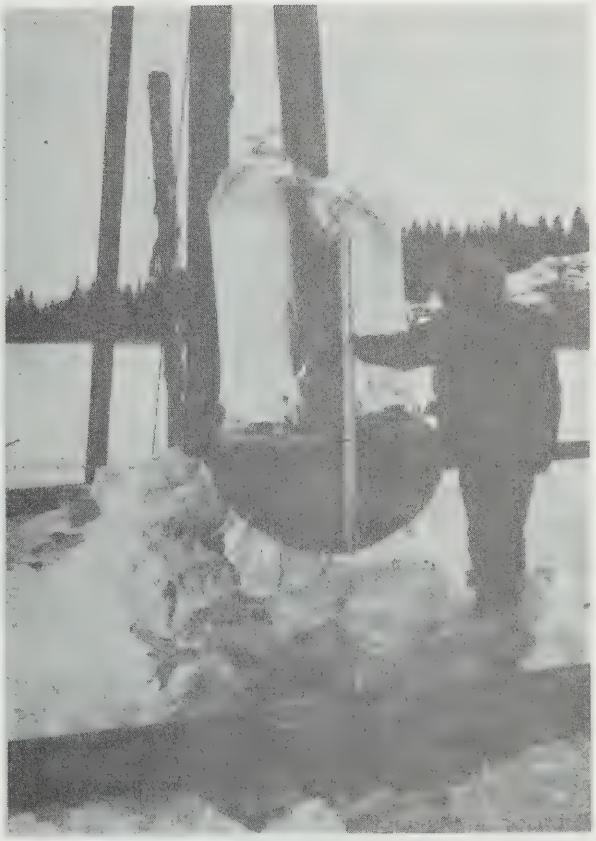


A-28

Cryopile #4 middle diameter 3.3'.

A-29

Cryopile #4 bottom diameter with frozen silt at bottom end of pipe.



A-30

Cryopile #4 showing depth of frost penetration into silt bed about 1.7'.

A-31 Close-up view of silt frozen onto bottom end of #4 cryopile (Freon 12)

A-32 Cryopile #4 - note that most of the ice has been removed to facilitate removal.

A-33

Cryopile #6 top diameter 2.9'.

A-34

Cryopile #6 middle diameter 2.4'. Note rope frozen into ice - left there by army divers.

A-35

Cryopile #6 bottom diameter 1.7'. Note hemisphere of frozen silt on bottom.

A-36

Cryopile #7 total ice on pile. Note no ice at base of pile.

A-37

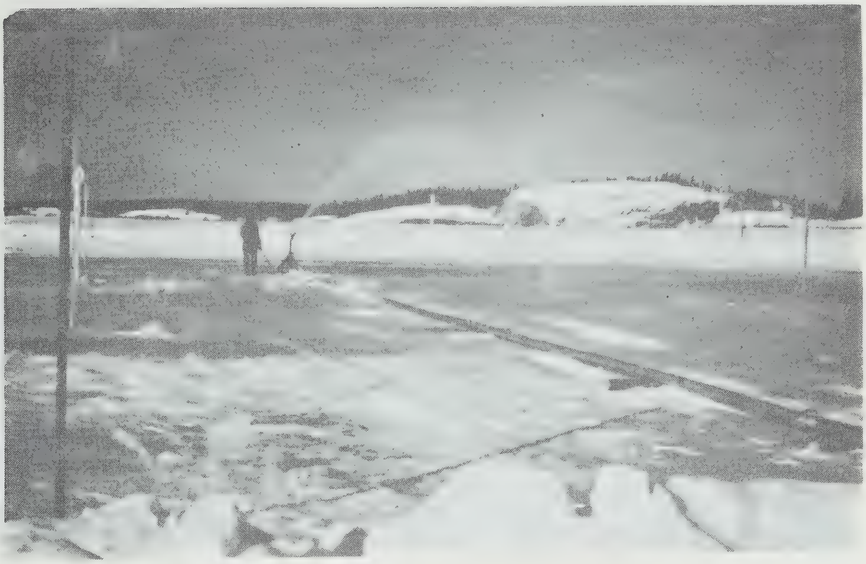
Cryopile #7 top diameter 1.7'. Note curvature into bottom of river ice.

A-38

Cryopile #7 middle diameter 1.4'.

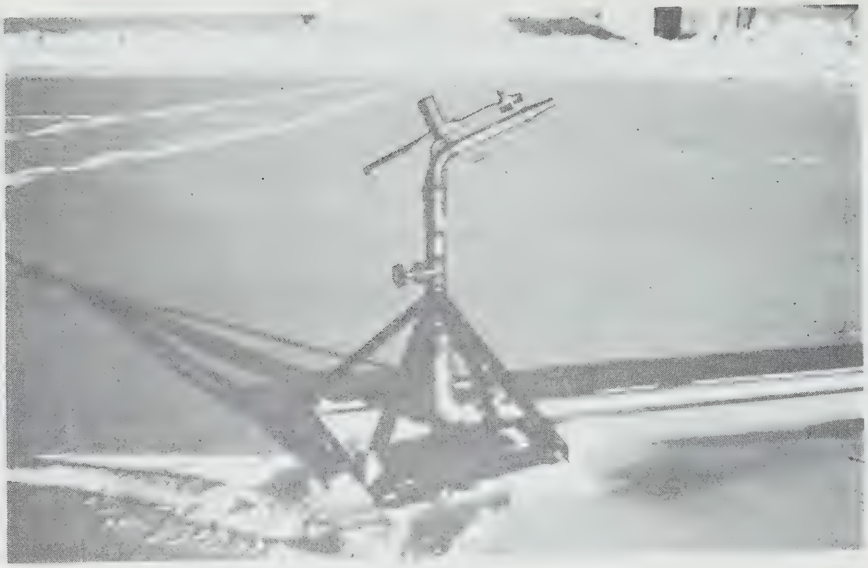
A-39 Operation of sprinklers - note how wind carries much of the fine spray away from the plot.

A-40 Plots 1 and 2 showing how ice was formed by sprinklers. Note operation here in plot 1 only.



A-41 Initial sprinkler operation with no insulation on pipes. System eventually froze up.

A-42 Final method of sprinkler operation with pipes insulated and elevated. Constant handling of pipes was thus done away with, eliminating pipe damage and shut down time for blocking.



A-43 One of the Buckner impact sprinklers before operation.

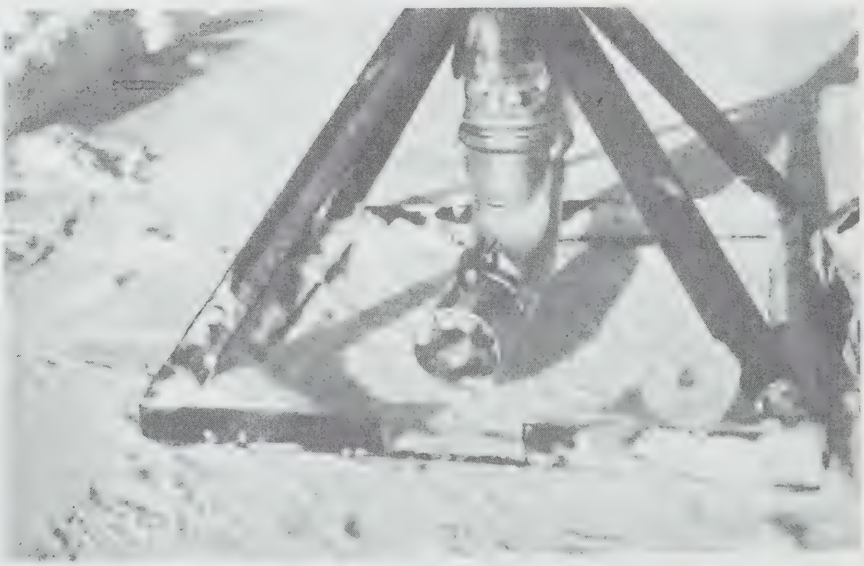
A-44

Impact sprinkler during operation. Note that driver is inoperational and insulation has been added to pipe.

A-45 Removal of ice from pipes with propane torches. Note high pressure pump located in heated shack.

A-46 Leaking pipe joints was one of the problems encountered during the experiment.

A-47 Pile of ice removed from 4-inch pipe prior to installation of heat tape and insulation.



A-48 Formation of ice inside pipes before use of heat tape and insulation.

A-49 Sprinkler operation in plot 1 -- note ice build up on grid posts.

A-50
Sprinkler operation with heat tapes and insulation around pipes held above the ice by blocking.

A-51

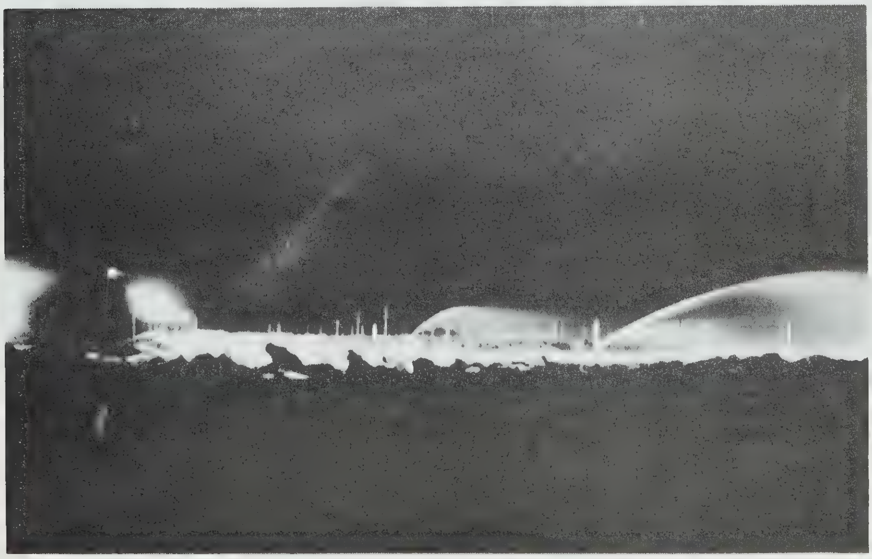
Ice buildup on grid posts which formed during sprinkling on plot 1.

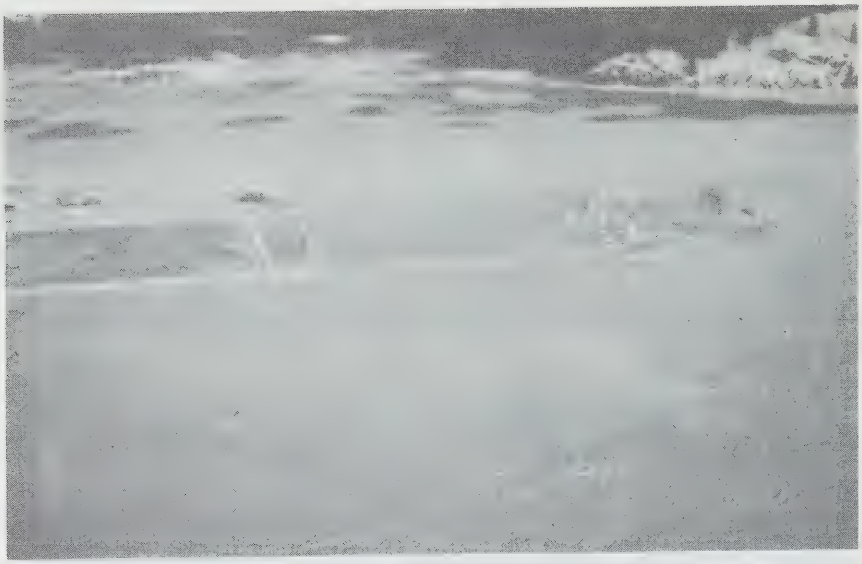
A-52

A-53

Night-time operation of sprinklers on plots 1 and 2.

A-54

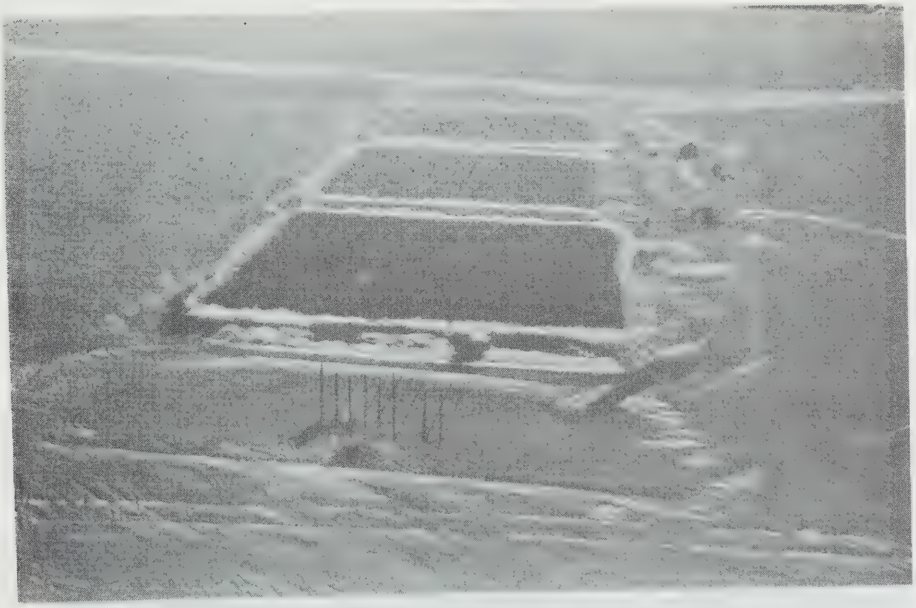




A-55 Aerial view of plot 3 which was flooded using a 6-inch low head pump. Dikes around plot were meant to retain water in the plot.

A-56 Shack used to house 6" pump for flooding. Suction hose and discharge hose can be seen leading away from shack.

A-57 View of flooding operation onto plot 3 using 6-inch discharge hose.



A-58 Aerial view of plot 3 shows water leakage through snow dikes. Sprinklers can be seen in background and cryopiles in foreground.

A-59

Method used to obtain ice blocks for density measurements. Water in hole comes from lenses of water which didn't freeze during flooding.

A-60 Ice made by flooding is characterized by various colored layers.

A-61

Measuring the thickness of the ice lifts.

A-62 Trimming the blocks of ice preparatory to measuring and weighing for density calculations.

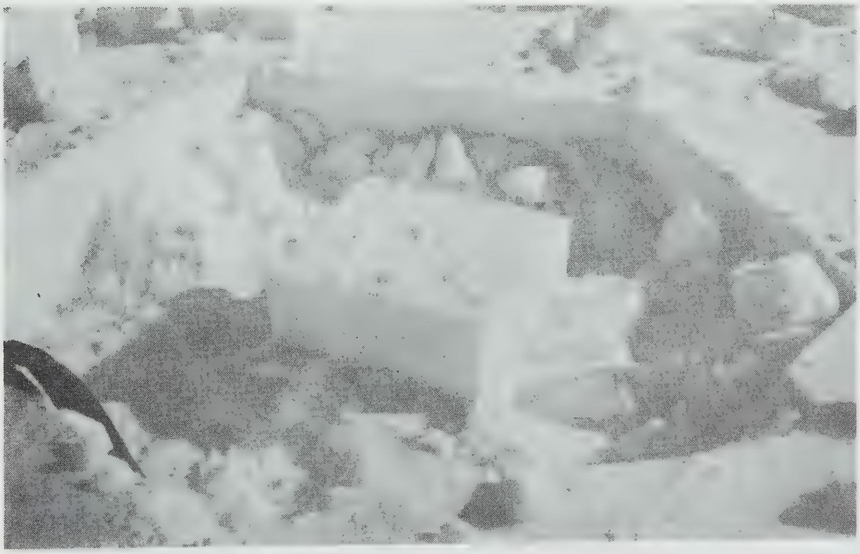
A-63

Typical sample of clear original river ice taken from below the ice made by flooding. Density about 55 lbs./cu. ft.

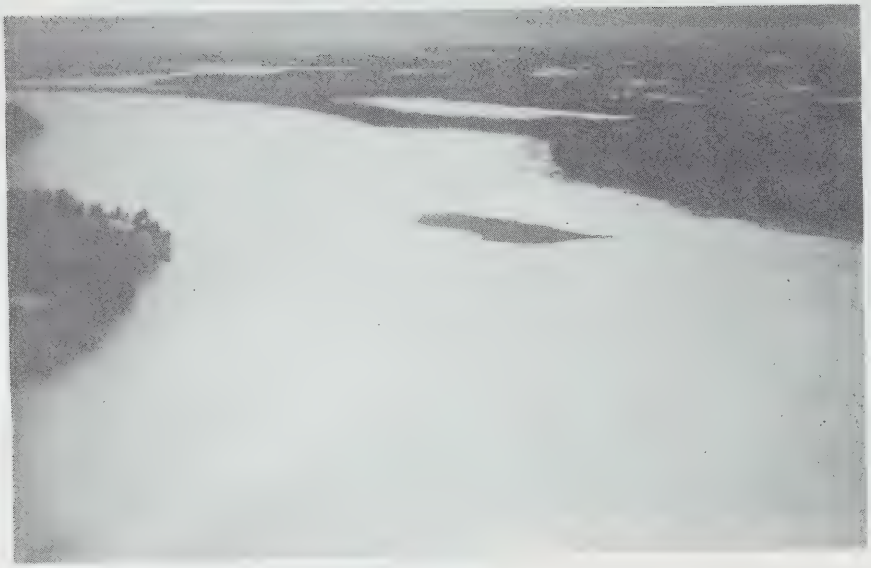
A-64

Sample of original river ice that was full of river silt. Also taken from below the ice made by flooding but in a different location from the one above. Density about 55 lbs./cu. ft.

A-65 Sampling from a mound of "snow-ice" that was formed by the fine spray of the sprinklers. Note the length of grid post still showing. Top of posts were 10 ft. above river ice at start of experiment.

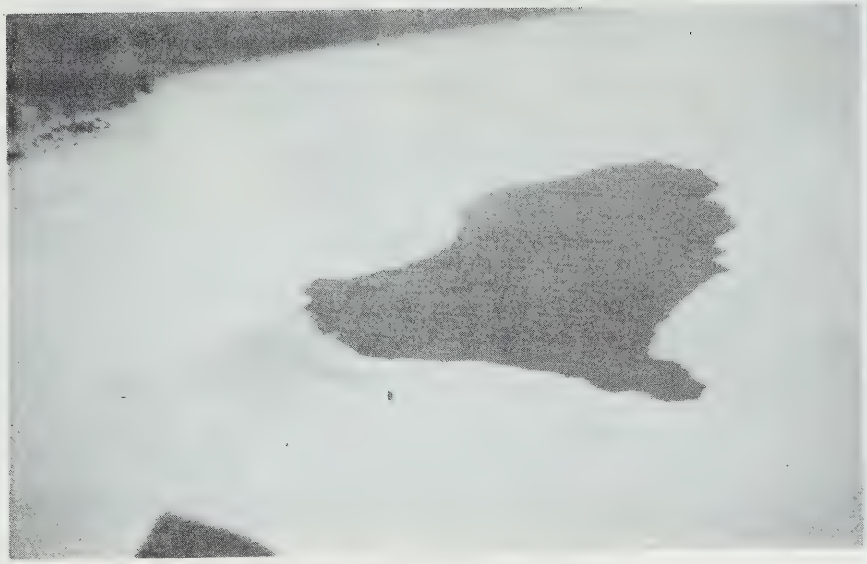


A-66 View of top of snow-ice mound. Density about 30 lbs./cu. ft.



A-67 Rivière des Rochers looking downstream at site of Little Rapids. Water usually remains open here throughout the winter.

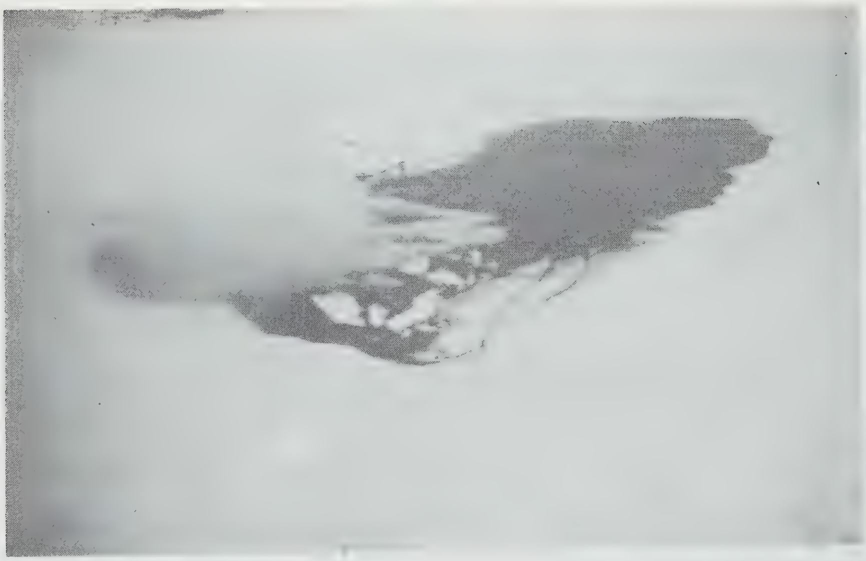
A-68 Open water at Little Rapids site. Mounds to the left of open water are bed rock.



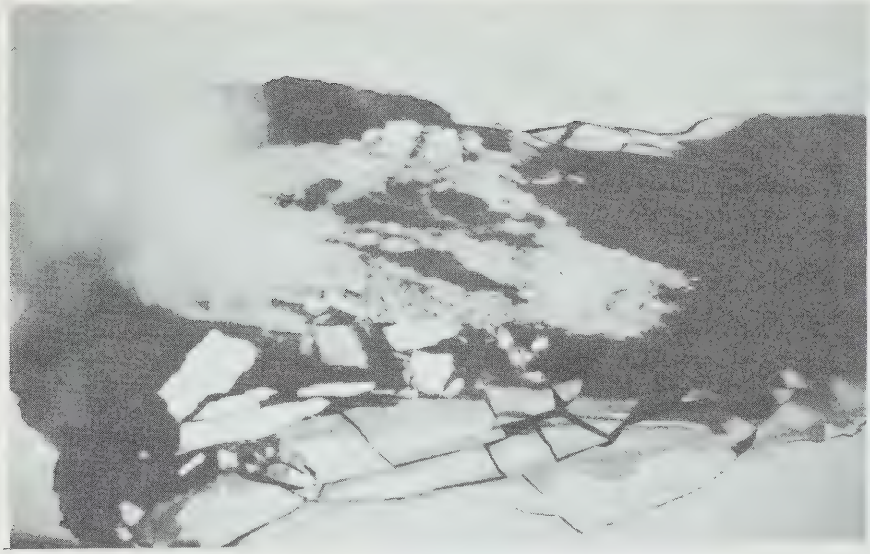
A-69 Placement of explosives in area (L. Center) upstream of open water.

A-70 Explosion #1, 2 to 2½ lb. charges - Feb. 20, 1972 - (total 162½ lbs.).

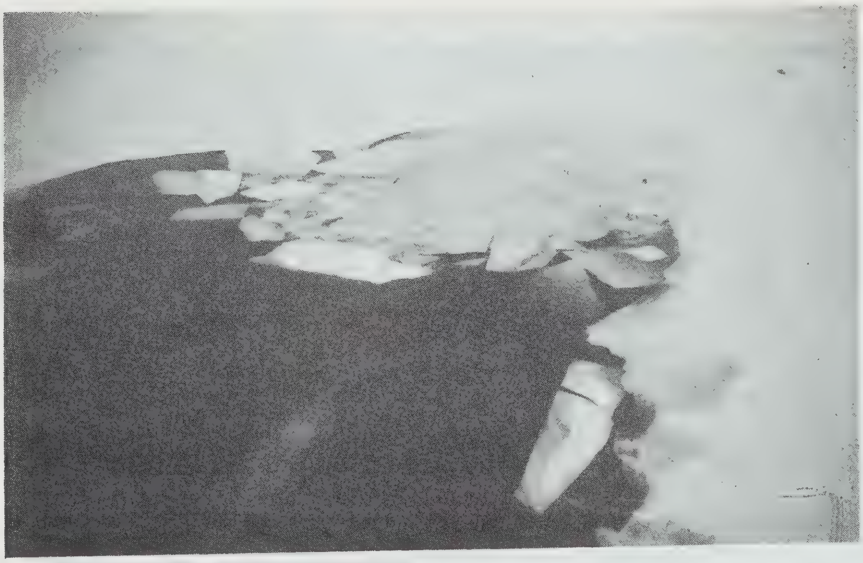
A-71 Explosion #1 - large floes breaking away from main ice adjacent to charges.



A-72 After explosion #1 more large ice floes breaking away from right side because of shock wave through the water. Notice the crushed ice floating downstream from the immediate area of the charges.



A-73 After explosion #1 notice the difference between the crushed ice from the blast area and the larger floes which broke away from the main ice.



A-74 After explosion #1 the crushed ice tends to jam at the surface, but note how the larger floes tilt downward and are taken under the surface ice.

A-75 After explosion #1 - note the edge of one large floe (1' to 2' thick) that has been drawn under by the current.

A-76 Explosion #2 - 2½ lb. charges (total 44 lbs.), Feb. 20, 1972.

A-77 After explosion #2, very few large ice floes, mainly crushed ice from blast area.

A-78 Explosion #3 - 1 lb. charges on 3 yard centers - total 29 lbs. Feb. 22, 1972.

A-79

Ice floes resulting from blast #3. Smaller charges (one lb.) appear to give better results, i.e. large blocks of ice with less crush ice.

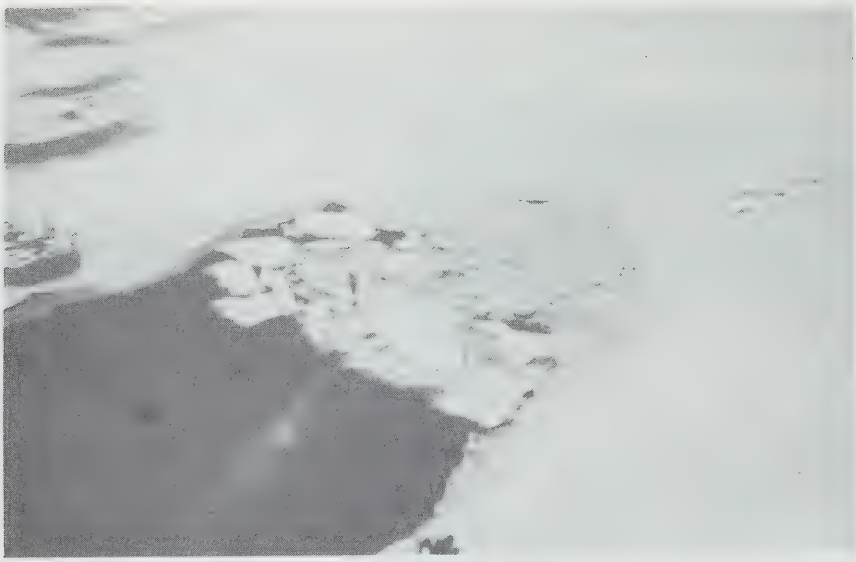
A-80

A-81 Explosion #4 - one 5 lb. charge - other charges misfired.

A-82

After explosion #4 - very little crush ice and one very large ice floe.

A-83 Explosion #5 - 40 lb. surface charge - only result was 4 ft. diameter hole in ice.



A-84 Final view of downstream end of open water. It appears as though only the thin ice from the initial explosion was drawn under the ice. The following heavier ice remained mainly on the surface.

APPENDIX B

LITERATURE REVIEW

APPENDIX B

Review of Literature

The following material is a summary of references which were considered important to the technical background for the ice dam project. Thermopiles, cryopiles or cells all mean in general the same thing.

1. "Ice Construction - Investigation of Accelerated Bottom-Freezing Techniques"; Technical Note N-1078 by C.R. Hoffman and L.R. Culbertson, February, 1970; Naval Civil Engineering Laboratory, Port Hueneme, California.

This technical note reviews possible methods for accelerated bottom growth on existing ice sheets and describes laboratory and field tests on the convection cell, a form of heat pipe operating by convection circulation.

Any ice-growth system to be used in remote areas must be:

1. Installed and operated with minimum equipment and man-effort.
2. Operable with minimum external power.
3. Capable of producing the required growth in minimum time.
4. Configured for easy installation and recovery and minimum interference with related surface activity.
5. Consistent with design maintenance criteria for preserving and stabilizing the ice structure.

Numerous techniques suggested for ice growth and bottom thickening fall into

three general categories; recirculating fluid, cold-fluid injection, and ice injection. All would produce an increased ice thickness on the underside of a floating ice sheet.

Recirculating-fluid systems for accelerated ice thickening may be classified according to decreasing external power requirements as follows: vapour-compression refrigeration systems, mechanically circulated liquid systems, and free-convection fluid systems.

Vapour-Compression Refrigeration

In these systems the working fluid, an amonia or freon refrigerant, is used to cool a less expensive secondary fluid. The secondary fluid is then circulated through buried freeze points to promote freezing. These have the advantage of promoting fast freezing at any ambient condition. This method has a high initial cost, high operating cost, and severe logistic limitations in remote regions.

Mechanical Circulation

When surface air temperatures are below freezing a fluid cooled to sub-freezing temperatures in heat exchangers at the surface, can be circulated through freeze points below the ice. Machinery and external power requirements for this system are substantially less than those for vapour-compression refrigeration but would still require extensive operational monitoring and logistical support.

Free Convection Fluid

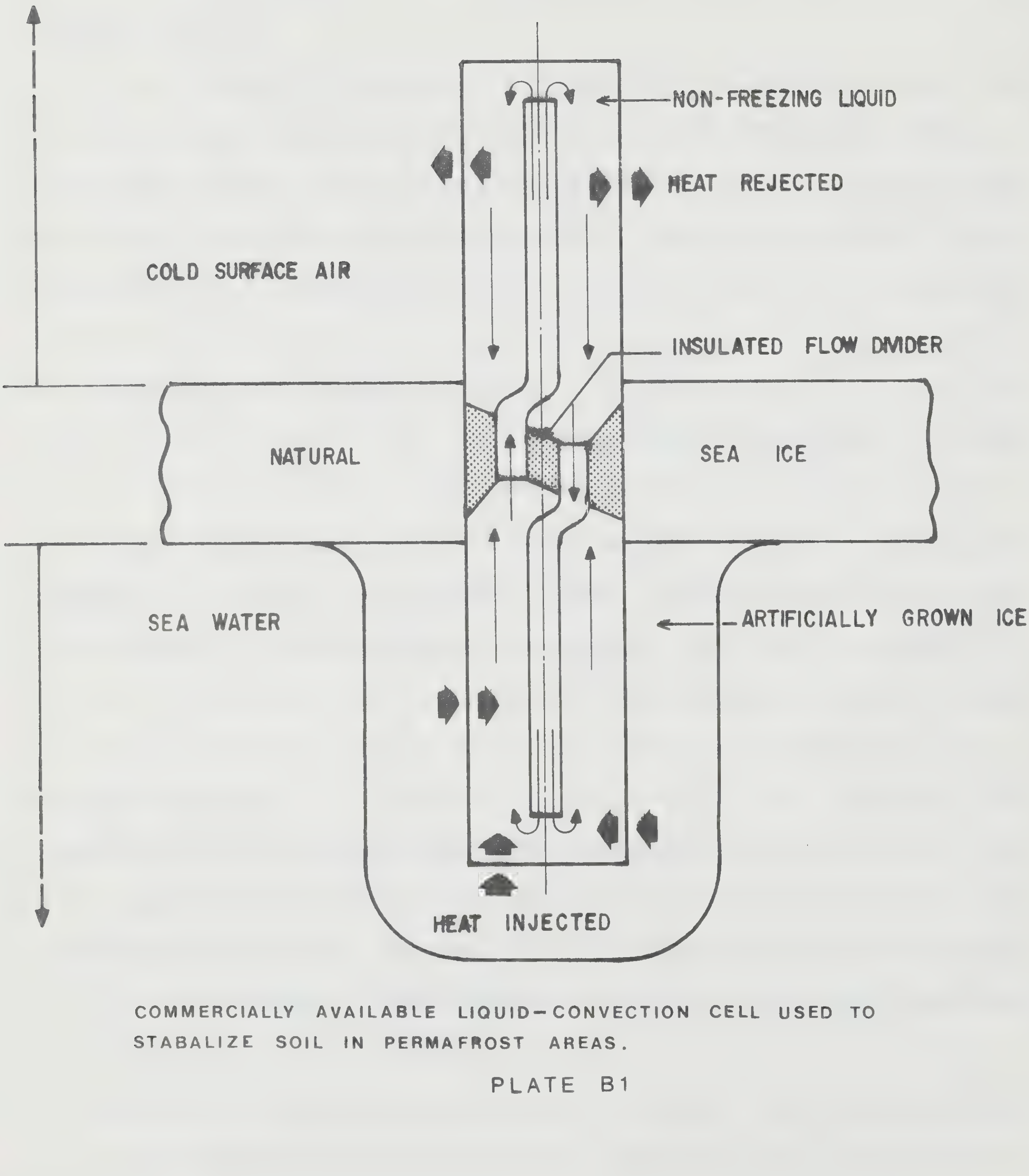
Two basic systems have been used to stabilize piling placed in permafrost.

These are: liquid convection and two-phase, boiling liquid and vapour convection.

The standard convection cell (Plate B1) is completely filled with a low-viscosity, high specific heat liquid such as a water-alcohol solution. For bottom ice formation the cold surface air would cool the liquid at the top of the cell, making it more dense. This cooled fluid, being heavier, would sink through the flow divider to the bottom of the cell, where it would be warmed by the heat of fusion from the forming ice. This warmed fluid now less dense, would rise to the top of the cell by convection, where the cycle would be repeated. This process is not reversible.

The two-phase convection cells are similar in outward appearance to the liquid convection cell but contain no internal tubes or flow dividers. For bottom ice formation a liquid with a low-boiling temperature would be heated by the heat of fusion of forming ice on the submerged portion of the cell. This liquid would vapourize and rise to the top of the pipe protruding from the ice, which would be cooled by the ambient air to provide a low temperature heat sink for the vapours to condense on. After condensation, the fluid droplets would run back to the bottom of the pipe where the process would repeat. A common working fluid is propane under a pressure of 30 to 60 psi, but butane and Freon C-318 may also be used at near-atmospheric pressures.

The major operational difference between the fluid convection cell and the two-phase convection cell is that the ice-forming end of the fluid cell can function at very low temperatures if the ambient air temperature is low but the ice forming end of the two-phase cell is limited to a specific temperature



COMMERCIALLY AVAILABLE LIQUID-CONVECTION CELL USED TO STABALIZE SOIL IN PERMAFROST AREAS.

PLATE B1

regardless of the ambient air temperature. At a very cold ambient air temperature the fluid cell would out-perform the two phase cell. At air temperatures just below freezing, the opposite would occur since the two-phase cell removes more heat per unit of fluid than the convection cell.

<u>Cold-Fluid Injection</u>

This consists of pumping a liquid or gas at a sub-freezing temperature under the surface of the ice sheet. The below-freezing fluid would produce ice growth by direct mixing heat transfer with the warmer water. This system is impractical because of the external power requirement and the difficulty in controlling the air below the ice sheet.

<u>Ice-Injection Method</u>

Relatively cold ice chips taken from a borrow pit would be injected below an ice sheet. The chips buoyed up to the bottom surface of a natural ice sheet would collect to form a new layer and thereby increase the total ice thickness. Ice chips injected rapidly enough would fuse together to the bottom of the natural ice sheet surface. Considerable equipment and man-effort are required for this method.

The foregoing review of potential methods for accelerated bottom growth of an existing ice sheet indicate that convection cells best fit the basic requirements. They are easily installed and are capable of operating without external power or surveillance.

Three types of convection cells were tested in a laboratory at surface air temperatures of 15^{o}F and -30^{o}F to determine their operating characteristics

under controlled conditions:

Balch Cell - liquid convection (2 parts by volume of alcohol to 9 parts distilled water at 15°F and 6 parts alcohol to 5 parts of distilled water at -30°F).

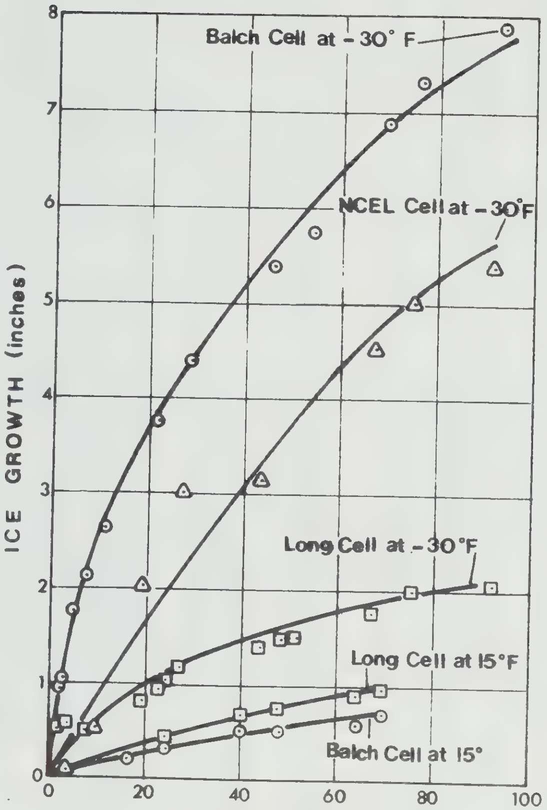
Long Cell - two phase, boiling liquid and vapour convection cell (Freon C-318).

NCEL Cell - a ducted two-phase, boiling liquid and vapour convection cell (Freon C-318).

Both the Balch and Long cells were made of 3 inch nominal black iron pipe, 7.5 feet long with external vertical heat rejection fins. The NCEL cell, operating on the same principal as the Long cell was fitted with internal piping and a non-insulated flow divider, and was fabricated from 12 inch aluminum pipe, five feet long, with the fins. Each cell was submerged in 30 ppt salinity sea water.

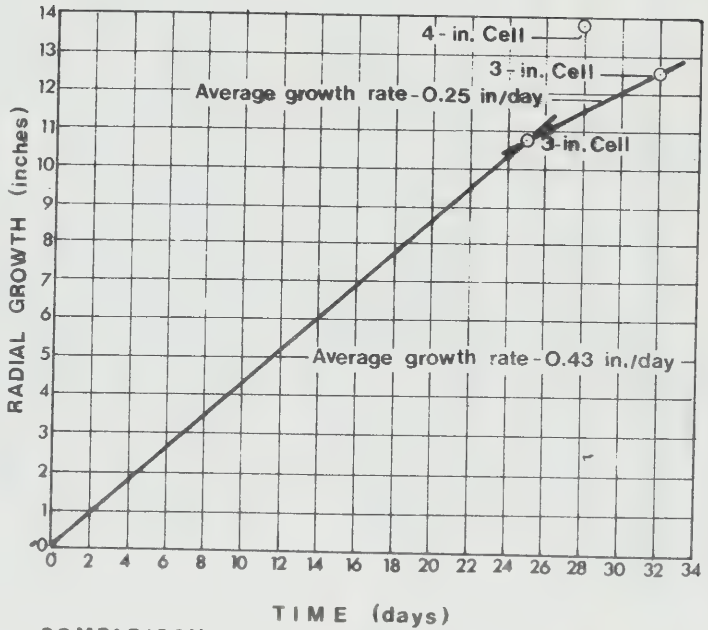
Plate B2 provides the test results. After 70 hours, at 15°F, the Long cell was the more productive with 0.90 inches of ice and the Balch cell was next with 0.75 inches of ice. After 90 hours at -30°F, the Balch cell produced 7.75 inches of ice, the NCEL 5.50 inches, and the Long cell 2.00 inches.

Based on laboratory tests three Balch cells were tested in natural sea ice. Two of the cells were made of 3 inch black iron pipe, 12 feet long. The third, painted white was made of 4 inch pipe 13 feet long. All three cells were charged with a 50-50 mixture of methyl alcohol and water having a freezing



TIME HISTORY OF CELL ICE GROWTH IN THE LABORATORY

PLATE B2



COMPARISON OF RADIAL GROWTH FOR THE THREE CELLS DURING THE MARCH-APRIL 1969 POINT BARROW FIELD TESTS.

PLATE B3

point of -40°F. Average temperature during a 32 day test was as follows:

Ambient Air	-5°F
Ambient Seawater	29°F
Cell heat-injection fins	0°F
Ice-pipe interface	18°F
Upper cell working fluid	11°F
Lower cell working fluid	17°F

Each convection cell produced a cylindical growth of ice along the entire length of cell below the natural ice sheet. In each case this ice was connected to the ice sheet with 4-inch radius fillet of ice; it was terminated with a hemisphere of ice below the bottom end of the cell. Plate B3 is a plot of average ice-growth for the three cells. Average growth rate for the 3 inch cells was 0.43 inches/day for the first 25 days and 0.25 inches per day for the next 7 days. This reduction in growth rate with time was also observed during the laboratory tests (Plate B2). The four inch white cell produced 54% more ice than the 3 inch unpainted cells after 28 days because of the large pipe surface for the 4 inch cell and absorption of less solar energy since it was painted white. During sunny days when the ambient air temperature was 18°F, solar energy warmed the fluid in the unpainted cells to 40°F. Ice growth around the cell had a smooth face unlike the bottom of the natural growing sea ice.

It was concluded that for maximum ice growth, liquid convection cells should be of maximum size and painted white.

II. "The Long Thermopile" excerpts from paper by Mr. Long, Chief, Soils Design Section, U.S. Army Engineers, Alaska; given at the International Conference on Permafrost, Purdue University, November, 1963.

The thermopile discussed is used as a soils foundation tool. It is described as a self-refrigerating unit with a high conductivity of heat out of the ground and a high resistence to heat flow into the ground. Subgrade cooling is a result of the condensation of propane vapours on the upper radiation surfaces of the thermopile. Condensation causes a reduced vapour pressure which permits boiling of condensate in contact with a warmer environment. The boiling condensate vaporizes and the vapour migrates to the upper radiation surfaces of the thermopile to complete the cycle.

All thermopile units operate at constant volume. Measured pressures have varied from 33.1 to 50.6 psi. Many installations have lost their charge through leaky fittings although the slow loss of propane would promote additional temporary cooling. It is suggested that all welds on thermopile units should conform to a local boiler and pressure vessel code, for unified pressure vessels. All installations are required to be tested along all joints, fittings and valves with a soap solution to detect the presence of the smallest leak.

III. Notes from Professor G. Locke, Mechanical Engineering Department, University of Alberta, to Peace-Athabasca Delta Project, 1972.

Technology

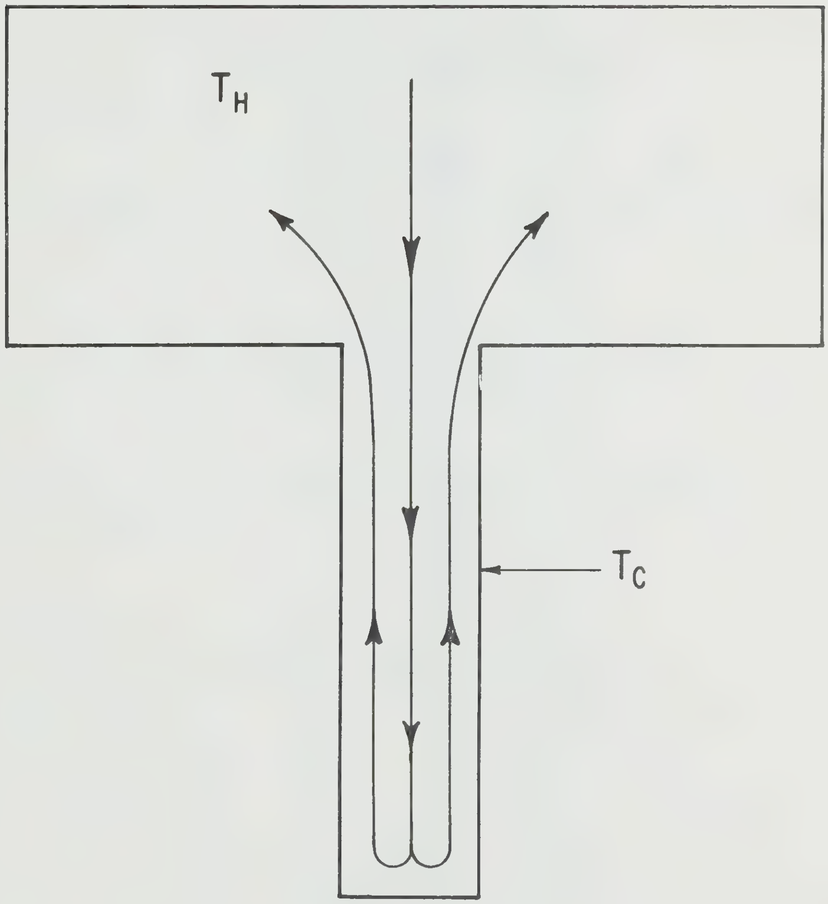
From among the various ways of making large quantities of ice, the method chosen for an ice dam must be efficient and inexpensive. The existence of low air temperatures provides a strong incentive to use the atmosphere as a large heat sink. However, to do this requires an effective mechanism whereby the latent heat extracted during ice formation can be dumped into the cold

prevailing winds.

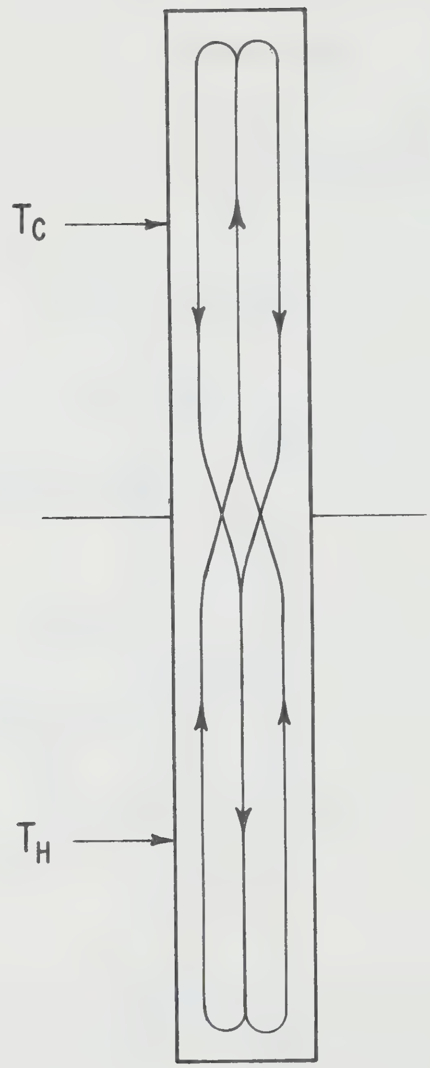
A natural convective system known as the thermosystem is shown in its several forms in Plates B4, 5 and 6. The open system shown in Figure 1 consists of a vertical tube closed at the bottom but opening at the top into a reservoir of cold fluid. When the wall temperature (Th) is above that of the reservoir fluid (Tc), the fluid circulator takes the form of the pattern shown. This convective system is capable of removing large amounts of heat but suffers from the disadvantage that a large reservoir of fluid is required. Only if the fluid itself was air would this be economical but unfortunately air is not an effective thermosystem fluid.

To circumvent the need for a reservoir is the closed system shown in Plate B5. This thermosystem is about twice as long as the open system and completely seals off the fluid at bottom ends. Its ability to extract heat is about one-half the corresponding value for the open system but it requires much less fluid and can be left to operate unattended for long periods of time.

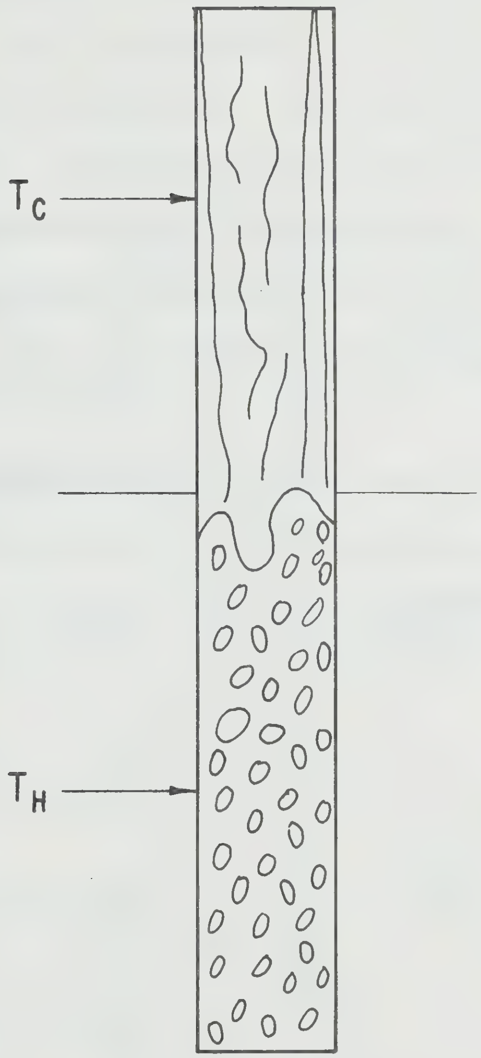
The closed single-phase system may be used in a device known as "cryopile". A cryopile standing in water would begin to make ice around its immersed length as soon as the air temperature dropped below 32°F. For an 8" diameter (Freon 12) cryopile standing in fifty feet of water and extending an equal height above the water, the rate at which ice begins to form would be 0.4 square feet (50 ft. high) per week when the air temperature is 0°F. The rate of ice formation is approximately tripled if the same diameter pipe is used in five feet of water and the air temperature is the same.



OPEN THERMOSIPHON



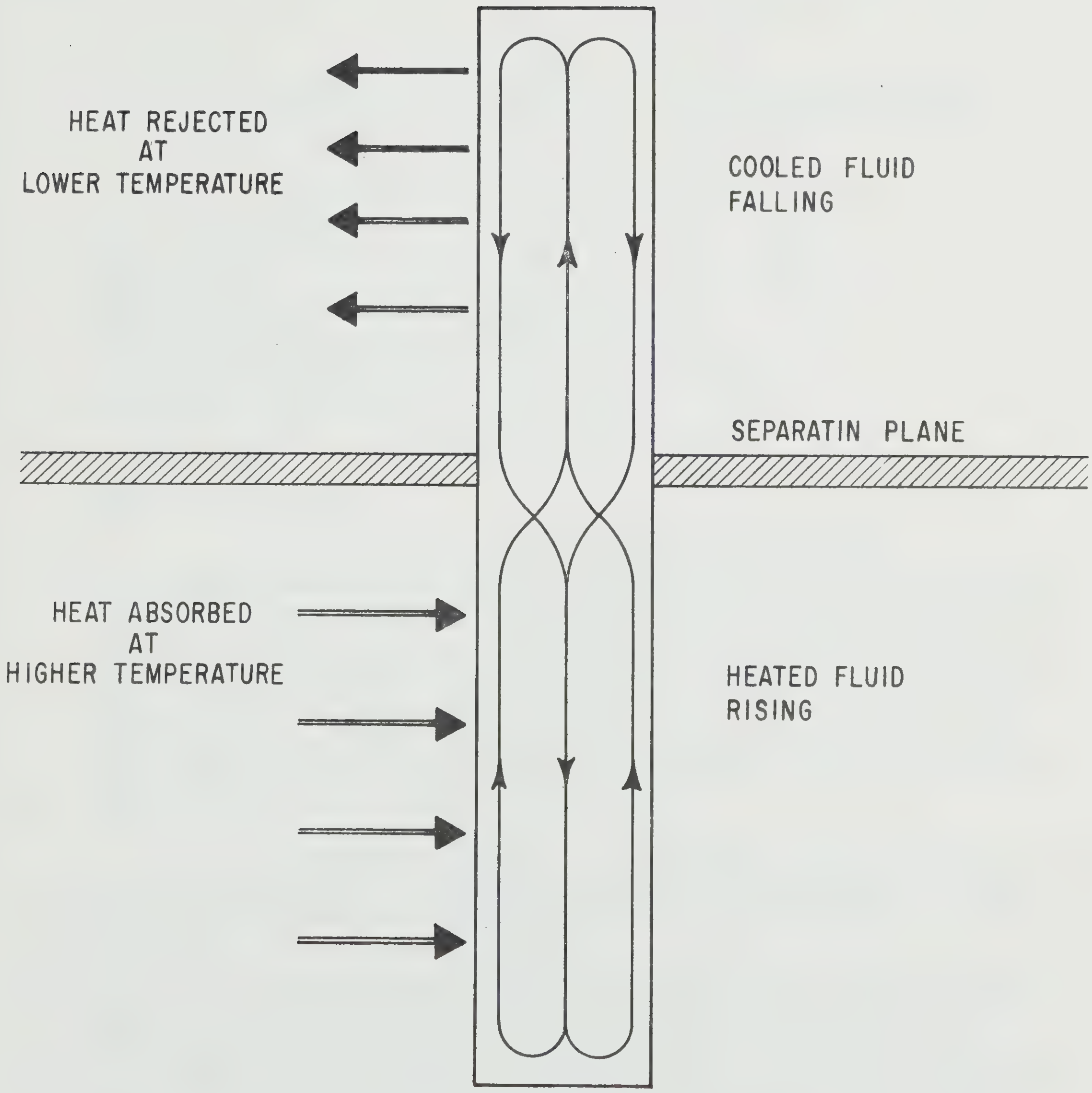
CLOSED SINGLE - PHASE THERMOSIPHON



CLOSED TWO-PHASE THERMOSIPHON

A modification of the closed thermosystem is shown in Plate 6. This illustrates the same closed tube with heat being extracted by the bottom section and released by the top section. The difference is that the tube is only partly filled with a fluid chosen such that it boils in the bottom section and recondenses in the top. Heat flows and boiling and condensation are much greater than in the single phase system, a typical gain being a factor of ten. Thus if the single phase system mentioned above was used in a boiling mode, the quantity of Freon required would be reduced and the rate of ice formation would increase to about 4 square feet (50 ft. high) per week.

It is apparent from the above that a cryopile operating on the two-phase closed thermosystem principle provides an attractive means of forming large amounts of ice from lake water in a cold climate.



THERMOSIPHON PRINCIPLE

(FLUID CONVECTION)

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DIVISION DES RECHERCHES EN BÂTIMENT

OTTAWA, CANADA
K1A OR6

15 December 1971

Mr. D.M. Hornby,
Director,
Peace-Athabasca Delta Project,
512 Baker Centre,
10025 106th Street,
Edmonton, Alberta.

Dear Mr. Hornby,

It was indeed a pleasure to have the opportunity to discuss with you and other members of the Technical Committee the problem of constructing ice dams in the Peace-Athabasca Delta area. As you requested, I will attempt to summarize briefly my first reaction to this proposal. It is quite difficult to foresee all the problems that may arise for, as far as I know, this is the first time anyone has considered constructing an ice dam for the purposes you envisage.

I think the report correctly identifies the two major problems (a) to obtain sufficient rate of build up of the ice mass and (b) how to effect river closure.

Considering the first problem, I do not think it is possible to build an ice cover 60 feet thick using the flooding techniques developed for construction of ice roads. In Alaska* ice roads 5 to 6 feet thick have been constructed in a little over three weeks using surface flooding techniques. If they had continued the procedure for 3 months they probably could have built an ice cover 20 feet thick. I would judge that at your site 20 feet would be about the maximum thickness of

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* Alaska's Amazing Winter Road,
Western Construction, June 1969

ice that could be built up by surface flooding during December, January and February. This rate of build up agrees reasonably well with the estimated theoretical rate (page 8 of the report), after some allowance is made for a curing period to allow freshly formed ice to solidify completely.

It is possible that ice thicknesses greater than 20 feet could be achieved by spraying water or by using artificial snow-making equipment combined with surface flooding and packing. Some of the more recent artificial snow-making machines have a high rated capacity. One manufacturer* claims that one spray gun can cover a 60,000 square foot area with 8 inches (water equivalent) of ice in 24 hours. If these ratings are correct then it might be feasible to build an ice layer 60 feet thick over a 3 month period at your site. Considerable field testing would be needed to develop the techniques and to ensure that any full scale program has a fighting chance of success.

The problem of effecting closure is perhaps more difficult than that of building up sufficient ice. As the thickness is increased by depression due to build-up on the surface, the cross sectional area of unfrozen water under the ice will become smaller and the head will increase until quite high velocities are attained. The ice being forced downward may rest on channel irregularities and may never completely shut off water flow no matter how much ice is accumulated. I do not think enough is known about the performance of thermo syphons and the proposed cooling pipes in the riverbed to be sure that they will be the answer to this problem. At some point the rate of heat transfer from the swiftly flowing water between ice around the cryopiles and pipes will balance the heat extracted by the refrigeration system. In my opinion, the cryopiles would probably have to be spaced much closer than the suggested 5 foot spacing to bring about closure. About the only way you can obtain reliable information on this is by installing a few test cryopiles under the ice cover in a river.

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* RAB Engineering Ltd.,
85 Brisbane Road,
Downsview, Ontario.

At the meeting we did discuss other methods of producing closure. If the proposed ice dam was built downstream from a frazil ice producing rapids it might be possible to produce blockage using the frazil ice. If the temperature of the water flowing under the natural ice cover is slightly below the freezing point (supercooled) the problems of complete closure would be simplified. A possible site where advantage could be taken of frazil-producing rapids was suggested and should be looked at this winter.

Assuming that an ice dam of suitable size can be constructed and closure effected, there remains the problem of preventing leakage through the dam or through the soil under the dam. By late June or July, ice temperatures within the dam are likely to be close to the melting point. If fissures or drainage paths develop, water under pressure will quickly melt a path through the dam and the erosion and failure of the dam might occur fairly quickly. It is difficult to estimate how serious this problem would be as it depends on how solid the ice cover is and how effective closure has been.

In summary, I think it would be premature to start construction of the proposed ice dam without much more investigation. The experiments planned for this winter on determining the maximum rate of ice production and freezing rate of the thermosyphons are a necessary first step. The proposal to investigate all possible sites is also necessary as the choice of site may well determine the success or failure of the project. If the preliminary tests this winter are encouraging it would be desirable to construct a much smaller dam, on a trial basis on a smaller river, to prove out ice-making and closure techniques, and problems with leakage, before constructing an ice dam of the size envisaged.

I hope these few remarks will be of value to you. If you have further questions or think we can help you further please do not hesitate to contact us.

Yours sincerely,

Gaynor Williams

G.P. Williams,
Geotechnical Section.

GPW/jo

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APPENDIX C

ICE MAKING EXPERIMENTS

APPENDIX C

DESCRIPTION OF ICE MAKING EXPERIMENTS

During preliminary attempts at designing some manner of ice dam, many questions or unknowns arose which couldn't be answered either referring to the scant literature available or by consulting with people knowledgeable in the field of ice problems. For instance, it was felt that no more than thirty to thirty-five feet of ice could be built up in any channel around Fort Chipewyan during an average winter using standard flooding procedures, (i.e. pump and hose). Considering the fact that it might be necessary to develop more than twice this amount of ice, it meant that some other means of building up ice would have to be found.

This latter point brought on an abundance of suggestions such as: (1) developing a system of high pressure sprinklers which could be operated continuously and would supposedly develop ice quite rapidly because water drops in the spray would become partly frozen before hitting the ice, (2) hauling or conveying ice blocks which have been blasted from a river channel or lake in the vicinity of the damsite, (3) blasting ice upstream of the damsite and a set of rapids so that the resultant blocks of ice would be sucked under and caught beneath the dam, thus constructing a hanging dam, (4) circulating a brine solution through a maze of pipes laid along the river bed at the damsite, so as to develop a well anchored layer of ice, and (5) maintaining a large open area immediately upstream of the dam to permit large amounts of frazil ice to be generated and caught beneath the dam as its being constructed.

Further was the problem of closure, which would likely be the most important design aspect to be considered and which has been discussed previously. Again this problem brought on many suggestions such as: (1) constructing some rows of cryopiles across the channel along the leading edge of the ice dam, to act as both an anchor for the ice mass and a means of effecting rapid closure, (2) placing a screening material across the channel, down from the upstream edge of the dam, which would trap frazil ice, ice blocks or perhaps some debris which would plaster itself on the mesh, and (3) injecting liquid nitrogen at a high enough rate to develop the necessary rate of ice build-up to effect closure.

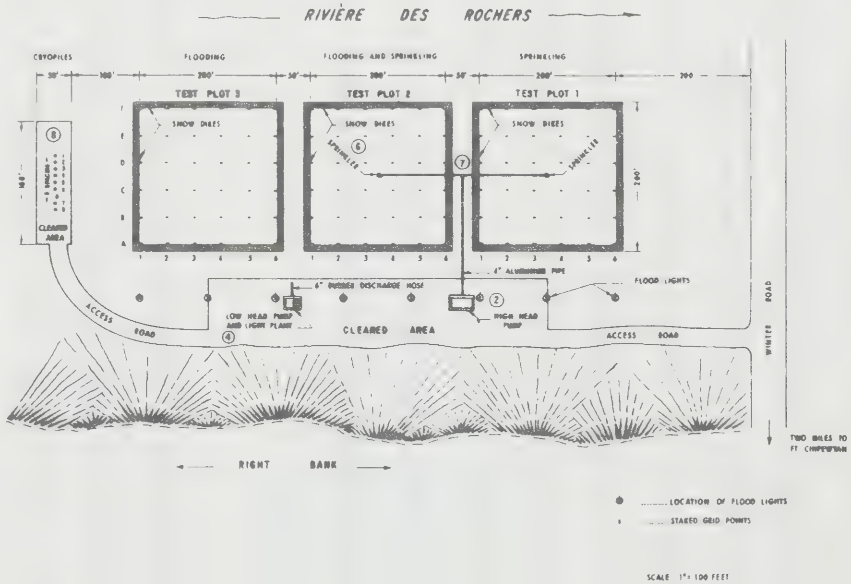
In order to add to the paucity of practical data, it was decided to carry out some field studies. Some idea of rate of ice build-up from standard flooding procedures is available from ice bridge construction reports, (Gold, 1960); rate of ice build-up around cryopiles has to be extrapolated from laboratory models or derived from solution of theoretical equations; and limited results have been published from the few previous field studies with cryopiles and sprinklers carried out by some American agencies, (Hoffman and Culbertson, 1970).

Two separate field studies were established during the period January to March, 1972, and were located on Rivière des Rochers near Fort Chipewyan and at Lambton Park, Edmonton. Following is a detailed description of the kinds of test programs established and the means by which these tests were carried out.

Fort Chipewyan Experiments

The objectives of the studies carried out on the Rivière des Rochers were to: (1) establish at what rate ice could be built up via flooding with pump and hose, (2) establish at what rate ice could be built up using one kind of sprinkler, (3) establish at what rate and to what extent ice would build up around a cryopile using two basic refrigerants, diesel oil and Freon 12, (4) look at the possibilities in blasting ice upstream of the rapids on Rivière des Rochers and having ice blocks catch on to the under-ice surface, and (5) in general establish what technical problems might be encountered under extreme cold temperature conditions.

Plate C1 outlines the primary work area on Rivière des Rochers. It shows three areas, each about one acre, and a row of eight cryopiles located immediately upstream of Test Plot 3. Each of the test plots were delineated into forty foot square grids and 2" x 2" boards were marked and frozen into place at each of these grid points (see Plate A6 and A51 for the purpose of measuring ice build-up. Snow dikes were constructed around each test plot. A Buckner sprinkler (Type 910) was set up at the centre of Test Plots One and Two. These incorporated three separate nozzles which helped deliver water fairly evenly in a 100 foot radius at an operating pressure of 180 psi. A mechanism was available which would turn the sprinkler automatically. Water was delivered to each sprinkler via four inch irrigation pipe fitted with quick couplers. A ninety degree elbow, a 2" x 4" reducer and valve were attached immediately up-line of the sprinkler and the whole assemblage was fitted inside a steel stand which left the sprinkler thirty inches off the ground (see Plate A43 for this set-up). A high head Gorman-Rupp (4") pump powered by a gasoline engine was used to obtain water and provide the



NOTES

1. LONDON SELF-PRIMING 6" CENTRIFUGAL PUMP POWERED BY 6 CYLINDER FLAT HEAD ENGINE USED FOR FLOODING
   - CAPACITY APPROXIMATELY 500 IGPM
2. GORMAN RUPP - 4" HIGH PRESSURE CENTRIFUGAL PUMP POWERED BY 4 CYLINDER FLAT HEAD ENGINE USED FOR SPRINKLING
   - PUMP MODEL 54M2 TYPE CJ3A
   - CAPACITY 350 GPM @ 80 PSI
3. 2" SELF-PRIMING CENTRIFUGAL PUMP (MODEL S-7D) POWERED BY WISCONSIN HEAVY DUTY AIR COOLED ENGINE
   - USED TO FORCE CIRCULATE CRYOPILE #3, LATER FOR FLOODING PLOT #3
4. ONAN DIESEL ELECTRIC PLANT (LATER REPLACED BY SMALLER GAS PLANT)
   - 10 KVA SINGLE PHASE 120/240 VOLTS
   - MODEL 12.0DJC - 3CE/22-365
5. ONAN GAS ELECTRIC PLANT
   - MODEL 3.5CCK
   - 3.5 KVA
6. BUCKNER SERIES 910 IMPACT SPRINKLERS
   - NOZZLE SIZE 5/8 x 1/4 x 9/32
   - CAPACITY 117.5 GPM @ 60 PSI
7. QUICK COUPLING 4" COMMON ALUMINUM IRRIGATION PIPE
8. CRYOPILES - FABRICATED FROM 40' TO 45' LENGTHS OF 8 3/8" O.D. STEEL PIPE

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HYDROLOGY

ICE MAKING EXPERIMENTS ON RIVIÈRE DES ROCHERS NEAR FORT CHIPEWYAN

Scale: As Shown
Sheet 1 of 2

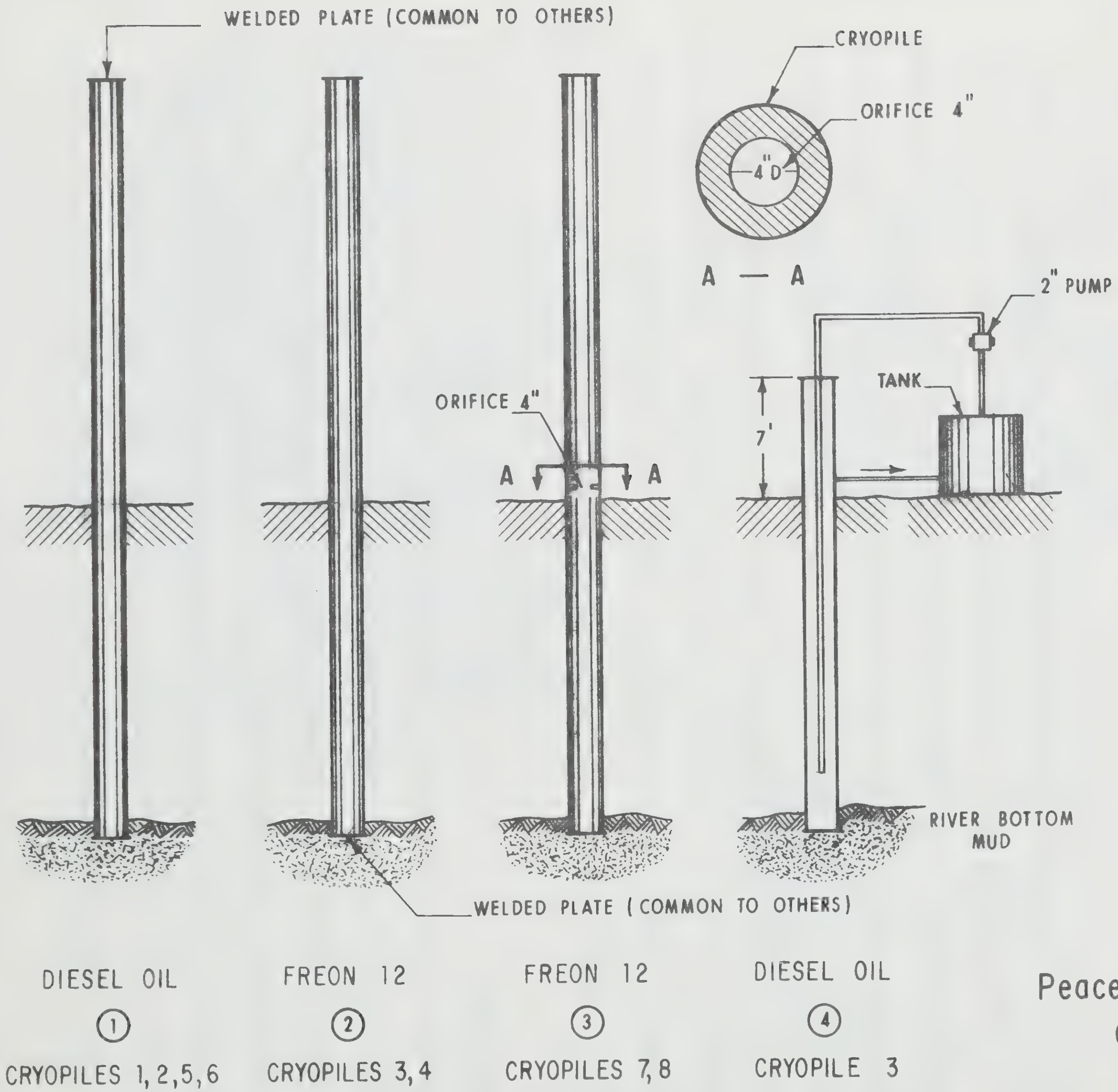
PLATE C1

necessary pressure to operate the sprinklers. The pump was housed in a building (see Plates A42 and A45) for pipe placement and pump location), while it was eventually found necessary to apply heat-tapes and insulation to the irrigation pipe in order to keep the system working. Freezing-up difficulties will be fully discussed in Appendix D but Plates A45, A47, and A48 show fully the final product of having water in the system freeze up. Each of the grid stakes was read about every eight hours while the sprinklers were continuously operating.

Test Plot 3 was used entirely for standard flooding procedures. A low-head, six inch pump powered by a gasoline engine was used to supply water via six inch rubber hose. Although the total length of the discharge hose was about two hundred feet, no particularly serious freezing problems were encountered because the flexible hose could be quickly drained after the pump was shut down. Water was delivered at the edge of the test plot and subsequently spread out over the entire test plot from that point. Test Plot 2 eventually became a standard flooding test site when it was found impossible to operate both sprinklers due to technical problems which will be discussed later.

Cryopiles:

Initially only six cryopiles were installed, with numbers 1, 2, 5, and 6 being filled completely with diesel oil and 3 and 4 being injected with 290 pounds of liquid Freon 12 each. Plate C2 is a summary of the types of cryopiles and refrigerants used. Eight inch steel casing with welded joints was used for the cryopiles with the average length of each cryopile being around forty feet. The cryopiles at least for the first three types, were of equal length below and above the ice. Cryopiles seven and eight differed



NOTES:

1. ALL CRYOPILE MATERIAL 8" I D STEEL CASING WITH WELDED JOINTS

2. 4 CRYOPILES OF TYPE 1
   2 CRYOPILES OF TYPE 2
   2 CRYOPILES OF TYPE 3
   1 CRYOPILE OF TYPE 4

3. TYPE 1; 2 OF LENGTH 45 FT. AND 124 GALLONS OF OF DIESEL OIL
   2 OF LENGTH 40 FT. AND 110 GALLONS OF DIESEL OIL

   TYPE 2; 2 OF LENGTH 40 FT. AND 290 lbs. OF LIQUID FREON 12

   TYPE 3; 1 OF LENGTH 40 FT AND 100 lbs. OF LIQUID FREON 12
   1 OF LENGTH 40 FT. AND 25 lbs. OF LIQUID FREON 12

   TYPE 4; 1 OF LENGTH 27 FT. AND 119 GALLONS OF DIESEL OIL

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CRYOPILE CONSTRUCTION
FT. CHIPEWYAN

PLATE C2

in that they contained an orifice just above the ice surface. It was argued that this would force a cross-over of the convection currents at the orifice, whereby the vaporizing Freon 12 would travel up the outside of the pipe below the ice surface and be forced to extend up through the centre of the pipe above the orifice. Condensing freon would drip down the outside of the pipe and would be forced to the centre at the orifice. The entire process was intended to improve the heat transfer qualities over Cryopiles 3 and 4. Lesser amounts of Freon 12 were injected in Cryopiles 7 and 8 (25 and 100 lbs. of liquid Freon 12 respectively). Injection of the Freon was a problem because no satisfactory commercial pump exists which would pump out the Freon 12 from a cylinder into a pipe. A propane torch had to be used to heat the cylinders in order to force the freon out of a cylinder. Also valves having Neoprene gaskets had to be used because Freon 12 would corrode and leak through a valve having a standard cork packing.

Cryopile 3 was revamped to include a system which circulated the refrigerant (diesel oil). This cryopile which was originally filled with freon developed a leak and the refrigerant escaped. The cryopile was cut down to within seven feet of the ice (ground) surface and a two inch steel pipe placed down the centre of the remainder of the eight inch pipe. A line connected to the cryopile at the ice surface allowed the diesel oil to drain into a forty-five gallon barrel and a two inch gasoline driven pump was used to pump the diesel oil out of this barrel back down through the two inch pipe which extended to within two feet of the bottom of the cryopile. It was felt that this circulation system would speed up the heat transfer rate between the bottom and top of the cryopile.

Plates A9 to A12 are a series of photographs showing the placement of the various cryopiles.

Ice Blasting

Canadian Armed Forces personnel (Canadian Airborne Regiment) in a cooperative venture were responsible for setting dynamite charges upstream of the rapids section in order to produce chunks of ice and to observe what would happen to these large chunks of ice when they reached the downstream end of the open water area. A reconnaissance of the rapids area last December (1971) indicated that a considerable depth of slush extended beneath the ice cover downstream of the rapids. This, it was reasoned, could be attributed to the fact that ice lenses (frazil ice) developed in the super-cooled water at the surface of the open water area in the rapids. It was felt that the volume of ice produced in this manner could be increased by maintaining a larger open water area. Also it seemed possible that if large blocks of ice were developed upstream of the rapids, they would be carried under the downstream ice surface and become attached to the mass of slush.

Army personnel attempted to set off four separate blasts at the upstream end of the rapids area, each one having a different spacing of charges. This was intended to produce four different size distributions of ice-block sizes. Plates A 67 to A 84 show the blasting program being carried out.

Summary of Operating Problems:

At this point some of the technical problems encountered during the testing program should be discussed.

(1) Leaks developing in some of the cryopiles was a constant source of irritation. These leaks occurred at welded joints and point out the necessity for ensuring high quality field welding together with a proper pressure resting program. It may be that some of the welds were adequate but fractures developed when cryopiles shifted around while being placed upright through the ice.

(2) Too many problems were encountered when attempting to start up the gasoline engines in extreme low temperatures. It would be more appropriate to use large electric generators to run electrically driven pumps.

(3) When flooding, one should use pumps with capacities no greater than about 100 Imp. g.p.m. The 1 cfs pump actually used was too large and a smaller two inch pump used near the end of the flooding program proved to be more adequate in terms of mobility and capacity. As suggested above, these pumps should be electrically driven partly because the small gasoline engines would not be durable enough to stand up to continuous use.

(4) Sprinklers should be used which would be able to rotate freely at any temperature. The sprinklers used were lubricated with a grease which was too heavy. Adequate lubricants should be found for low temperature operations.

(5) Ice produced by the sprinklers was more like crusty snow, as will be discussed later. It appears that the droplets of water were too small and were suspended too long before landing on the ground.

Sprinklers are available which will have a smaller radius of spray and larger drops of water. In this way the water will freeze on contact with the ground rather than in the air.

(6) Dikes around areas on which ice is being manufactured should be lined or sprayed with a coating of ice in order to prevent escape of water. One of the main problems which occurred on Test Plots 2 and 3 was the difficulty in keeping water in the test area from leaking out.

(7) Stand-by pump units should be kept on-site because of the remoteness of the area and the difficulty in servicing equipment.

(8) Any pipes feeding sprinklers should be insulated and provided with heat tapes.

(9) Cryopiles (two phase) should be fitted with pressure guages so that constant checks can be made on leakage of refrigerant.

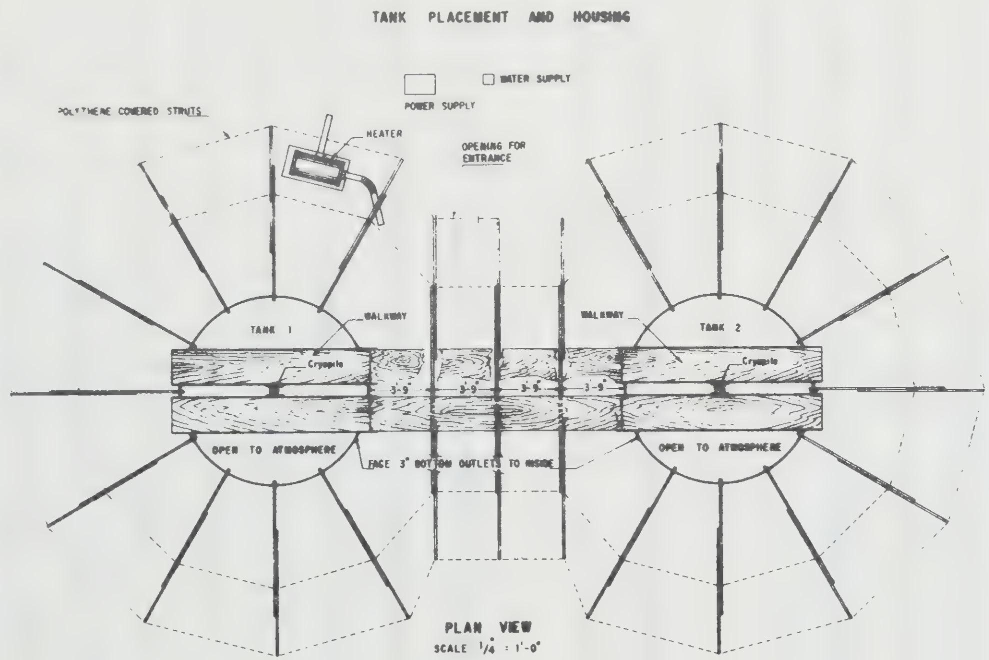
(10) A comprehensive set of field pressure tests should be derived to reduce the chances of placing cryopiles that might develop leaks.

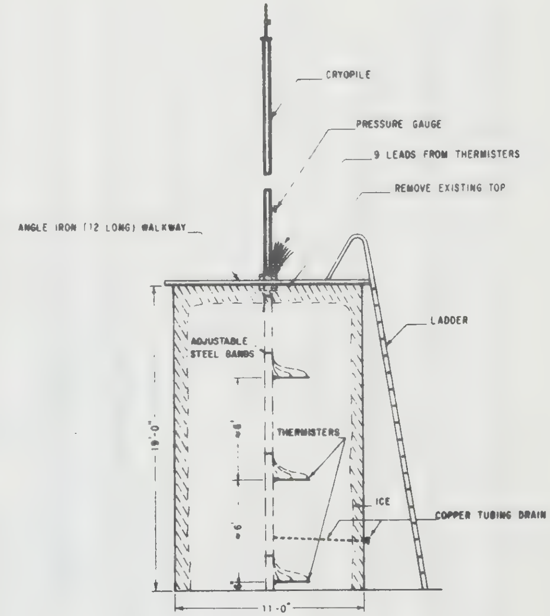
Lambton Park Experiments

The primary objective of the experimental facilty constructed at Lambton Park, Edmonton, was to observe and measure the rate of ice growth around cryopiles which were fairly extensively instrumentated for measurement of water and ice temperatures.

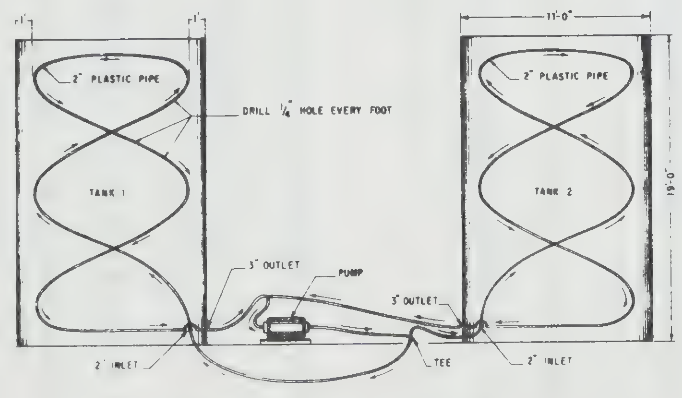
Plate C3 provides an overview of the experimental set-up. Two ten thousand gallon steel, water-filled storage tanks provided by Texaco of Canada Ltd., were housed in a polythene covered shelter. These tanks were nineteen feet high and eleven feet in diameter. Length of each cryopile was forty feet, with one filled with Kerosene and the other, 290 pounds of Freon 12. Each tank was connected to a four inch gas driven pump and water was pumped into the tanks through a series of small holes in a plastic pipe which extended throughout each tank. This was done in an attempt to maintain a homogeneous temperature throughout the tanks. If necessary, heat could be added to the water by heating up the interior of the shelter with a space heater. See Plate A3 for a photograph of this facility.

Plate C4 provides a plan of the physical makeup of the cryopiles used. Initially six inch diameter aluminum pipe was used for both cryopiles, but one was discarded (the one intended for the freon) because of the difficulty in welding pressure tight joints. Six inch steel casing was substituted and no leakage of freon occurred. The aluminum cryopile containing kerosene passed a pressure test prior to being installed in a tank, but unfortunately a leak developed sometime thereafter and kerosene drained out of the cryopile to about five feet above the surface of water in the tank. This leak was not discovered until about ten days after the experiment had begun.





PLACEMENT OF CRYOPILE IN TANK



CIRCULATION SYSTEM FOR MIXING AND ADDING HEAT TO WATER IN TANKS

NOTES

1. LONDON 4" SELF-PRIMING CENTRIFUGAL PUMP
   - POWERED BY 4 CYLINDER ENGINE
   - CAPACITY APPROXIMATELY 100 GPM
2. STORAGE TANKS (2) ON LOAN FROM TEXACO CANADA LTD.
   - CAPACITY 10,000 GALLONS EACH
3. CRYOPILES ONE ALUMINUM 40' x 6" I.D.
   ONE STEEL 40' x 6' I.D.
4. ANTHES SPACE HEATER - 350,000 B.T.U./HOUR
5. STEAM JENNY
6. P.V.C. - PLASTIC MISCELLANEOUS 4' AND 2" PIPE
7. TEMPERATURE SENSORS AND READ-OUT METER, YELLOW SPRINGS INSTRUMENT COMPANY

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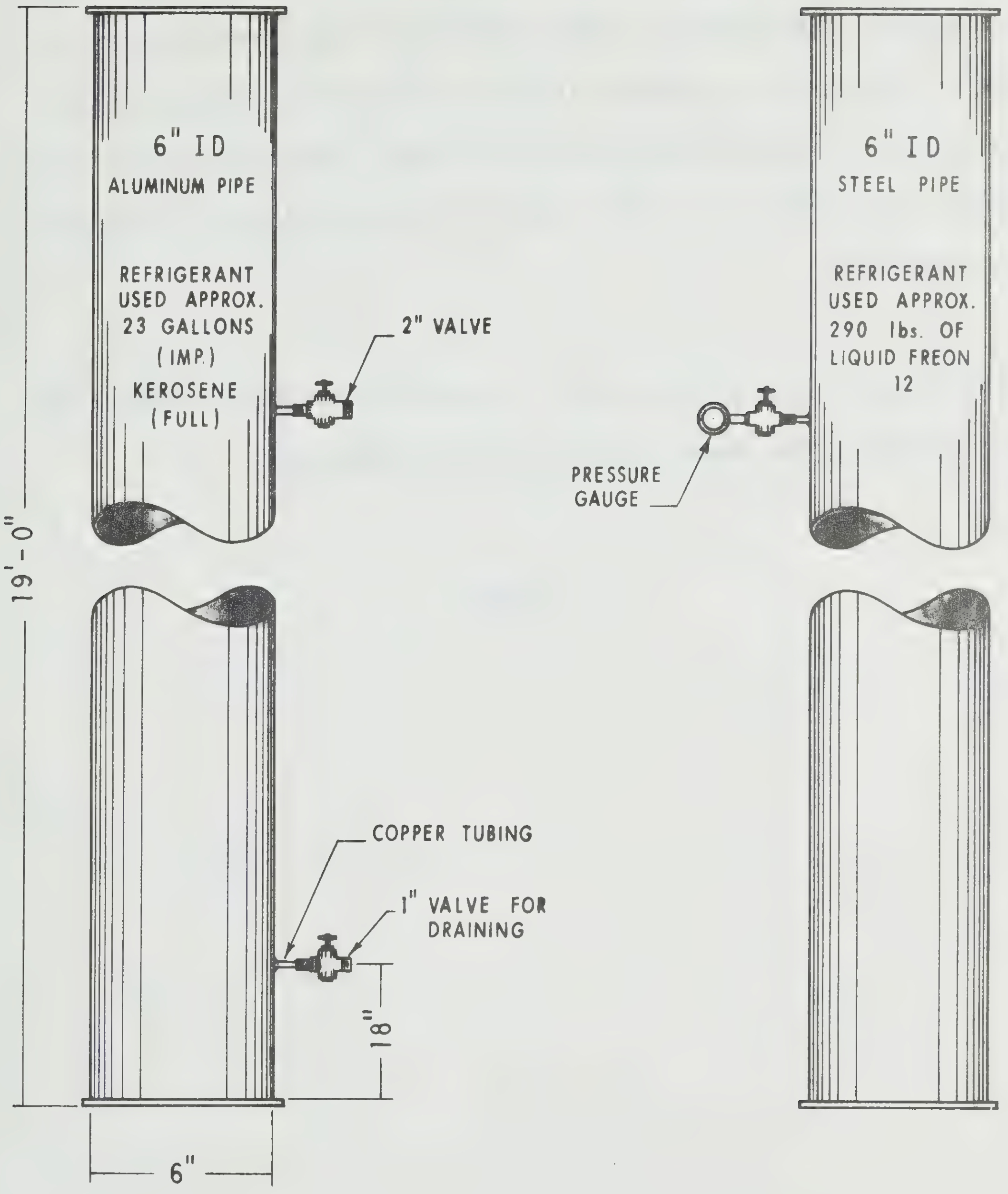
WATER RESOURCES DIVISION
HYDROLOGY

CRYOPILE EXPERIMENTS
LAMBTON PARK, EDMONTON

Sheet 2 of 2

PLATE C3



NOTE :

STRAIGHT - THROUGH PIPE USED FOR BOTH CRYOPILES. NO FITTINGS ATTACHED TO INSIDE OF PIPES FOR CIRCULATION OF REFRIGERANT OR IMPROVEMENT OF HEAT TRANSFER.

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CRYOPILE CONSTRUCTION
LAMBTON PARK, EDMONTON

Nine thermisters were attached to each cryopile (see Plate C3) with a set of three placed at the bottom, six feet and twelve feet from the bottom of the cryopile. Of this set one was placed at the outside surface of the pipe, the second six inches away and the third one foot away from the pipe. In addition, water temperatures were taken in the tank and at the outlet line from each tank.

Each of the cryopiles was painted white in order to reduce the amount of solar heat affecting the temperature inside the cryopiles.

APPENDIX D

APPENDIX D

DATA AND ANALYSIS, ICE (DAM) MAKING EXPERIMENTS

Fort Chipewyan Experiments

Studies began on February 11, 1972, with the placing of Cryopiles Nos. 1 to 6; flooding on Test Plot 3 commenced on February 17th; sprinkling on Test Plot 2; February 23 to March 1; flooding on Test Plot 2 commenced on March 4; and ice blasting trials at Rochers rapids were carried out on February 20 and 22.

Sprinkling and flooding tests were essentially completed by March 12th and March 17th respectively, and all cryopiles were removed by March 31st.

Meteorology

Daily temperatures during the above time period (February 11 to March 31, 1972) are plotted on Plate D1. Information was obtained from M.O.T. personnel at the Fort Chipewyan airport. The solid line designates the mean of the daily temperatures recorded at the ice-making site so that these are not computed on the same basis as the M.O.T. values since temperatures at the test site were sometimes read only two or three times during the day. Therefore one would expect the solid line to be somewhat above the dashed line, which indeed does occur. What this plot does indicate is that the temperature data from the airport is a good representation of what the temperatures were at the ice making site.

Also included in Plate D1 are the mean daily wind speeds as measured at the

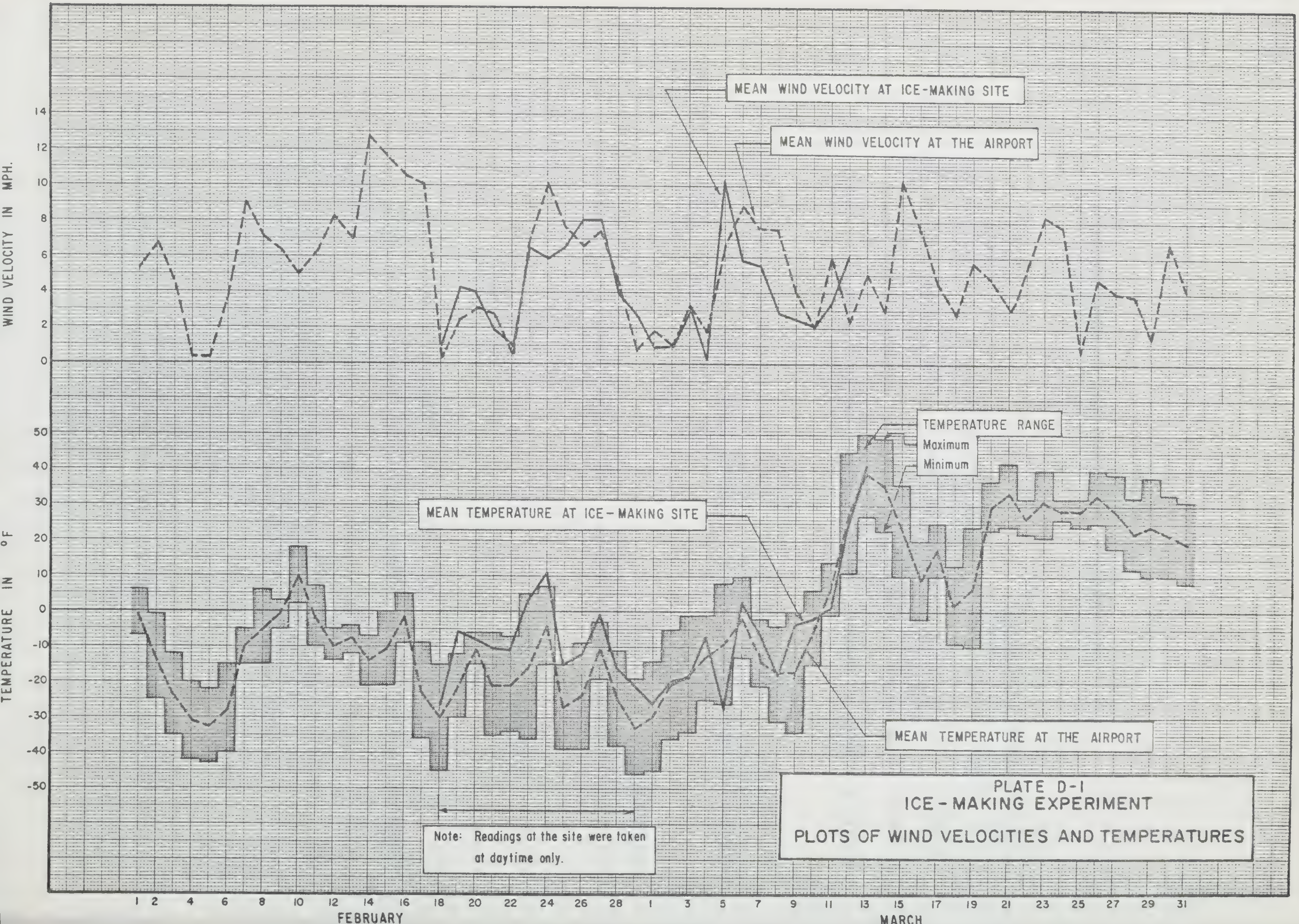


PLATE D-1
ICE-MAKING EXPERIMENT
PLOTS OF WIND VELOCITIES AND TEMPERATURES

airport and at the test site and again the differences are relatively small.

Summary of Temperatures

	Long-term Values		1972 Values	
	Feb.	March	Feb.	March
Mean Daily (^{o}F)	- 6.8	5.6	-15.5	10.8
Minimum (^{o}F)	-16.6	-4.9	-25.5	0.1
Maximum (^{o}F)	3.0	16.0	- 5.0	22.6

Observation of the above table indicates that temperatures in February were lower than average and in March they were higher.

A mass curve of degree-days of freezing is given in Plate D2, and is based on the mean-daily temperatures from the airport. The curve is quite uniform up to March 11, indicating that the freezing potential, without consideration of wind speeds, was fairly uniform throughout the time the bulk of the ice making occurred. After March 11th, temperatures went above freezing for a few days, after which a much smaller regime of freezing temperatures occurred.

Wind speeds varied up to twelve miles per hour and it appears from Plate D1 that the higher values occurred during periods of higher temperatures. Therefore smaller degree-day values (and hence smaller cooling rates) were partially offset by the increased cooling capacity provided by higher winds.

Cryopile Experiments

Table D1 is a summary of all cryopile measurements. These include the recorded circumferences, resultant estimated ice thickness in the radial

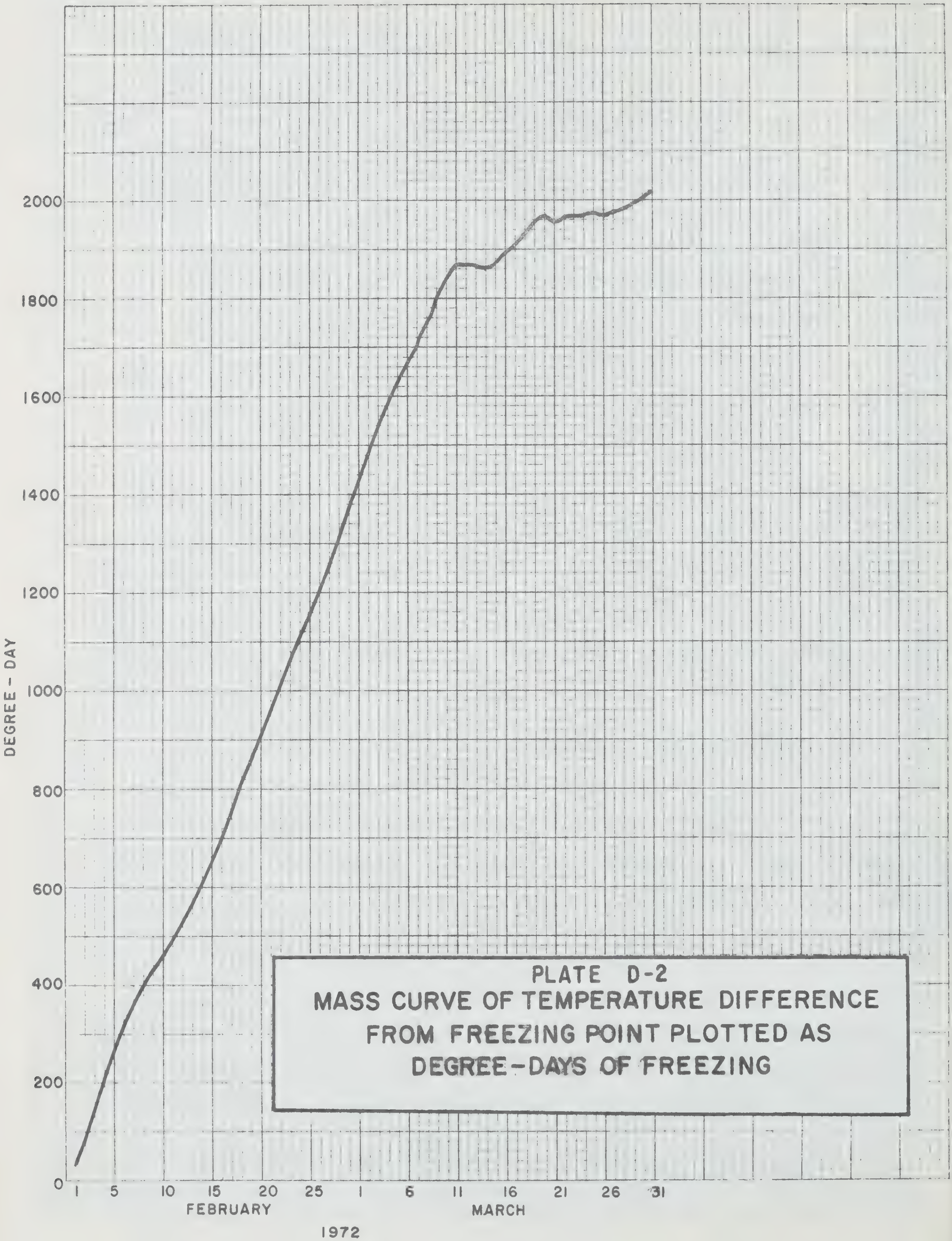


PLATE D-2
MASS CURVE OF TEMPERATURE DIFFERENCE FROM FREEZING POINT PLOTTED AS DEGREE-DAYS OF FREEZING

TABLE D-1

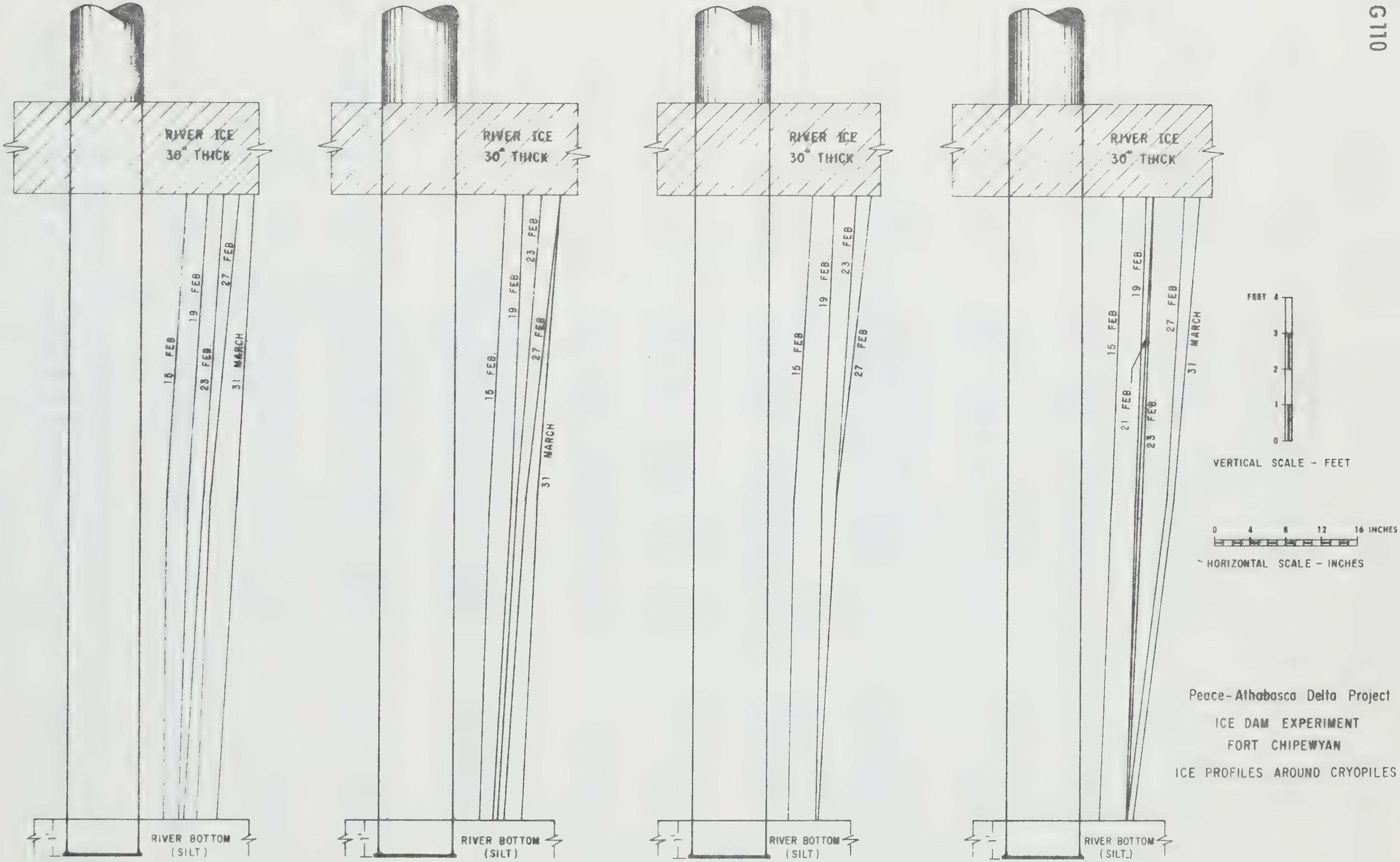
CRYOPILE NO.	DATE	TOP (1) CIRCUMFERENCE (INCHES)	TOP (2) RADIAL ICE THICKNESS (INCHES)	TOP (3) INCREMENTAL AREA OF ICE GROWTH ($INCH^2$)	TOP (4) AREA OF ICE ($INCHES^2$)	MIDDLE (1) CIRCUMFERENCE (INCHES)	MIDDLE (2) RADIAL ICE THICKNESS (INCHES)	MIDDLE (3) INCREMENTAL AREA OF ICE GROWTH ($INCH^2$)	MIDDLE (4) AREA OF ICE ($INCHES^2$)	BOTTOM (1) CIRCUMFERENCE (INCHES)	BOTTOM (2) RADIAL ICE THICKNESS (INCHES)	BOTTOM (3) INCREMENTAL AREA OF ICE GROWTH ($INCH^2$)	BOTTOM (4) AREA OF ICE ($INCHES^2$)	MEAN (IN^2/DAY)
#1	Feb 15	60	5.4	231.4	231.4	46	3.1	112.3	112.3	44	2.8	98.8	98.8	
	Feb 19	75	7.4	136.2	367.6	62	5.6	137.4	249.7	54	4.4	78.5	177.3	
	Feb 27	96	11.1	312.7	680.3	77	8.0	166.6	416.3	60	5.4	54.1	231.4	
	Mar 8	102	12.0	94.2	774.5			187.4e	603.7e	84	9.2	273.4	504.8	
	Mar 31	105	12.6	56.6	831.1	94	10.8	235.1	651.4					
	Averaged to Feb. 27 (in^2/day)				40				25				12.5	25.8
#2	Feb 15	62	5.6	249.7	249.7	52	4.1	161.3	161.3	45	3.0	105.5	105.5	
	Feb 19	74	7.6	132.6	382.3	68	6.6	150.0	311.3	56	4.7	88.2	193.7	
	Feb 23	87	9.6	165.2	547.5	71	7.1	34.8	346.1	60	5.4	37.7	231.4	
	Feb 27	101	11.8	206.7	754.2	78	8.2	81.8	427.9	64	6.0	40.3	271.7	
	Feb 29	105	12.5	66.9	821.1			10.9e	438.8e	68	6.6	39.6	311.3	
	Mar 31					83	9.0	64.1	492.0	75	7.8	85.8	397.1	
	Averaged to Feb. 29 (in^2/day)				43.2				23.05				16.4	27.5

TABLE D-1 (cont.)

CRYOPILE NO.	DATE	TOP (1)	TOP (2)	TOP (3)	TOP (4)	MIDDLE (1)	MIDDLE (2)	MIDDLE (3)	MIDDLE (4)	BOTTOM (1)	BOTTOM (2)	BOTTOM (3)	BOTTOM (4)	MEAN (IN^2/DAY)
#3	Feb 19	73	7.4	367.6	367.6	66	6.3	291.3	291.3	55	4.2		185.4	
	Feb 21	73	7.4	0	367.6	72	7.2	120.6	356.8					
	Feb 29													
	Mar 10									56	4.7	0.5	193.7	
	Mar 31													
#4	Feb 21	91	10.3	605.4	605.4	83	9.0	492.3	492.3	76	7.9	404.9	404.9	
	Feb 23					88	9.8	68.4	560.7	80	8.6	50.7	455.6	
	Feb 27	108	13.0	268.9	874.3	105	12.5	260.4	821.1	90	10.1	431.7	587.3	
	Mar 8	109	13.2	16.3	890.6									
	Mar 31	132	16.8	439.0	1329.6	128	16.2	430.5	1251.6	109	13.2	308.3	895.6	
	Averaged to Feb. 27 (in^2/day)				67				63				45	58
#5	Feb 15	58	5.0	213.7	213.7	47	3.3	121.6	121.6	43	2.6	92.3	92.3	
	Feb 19	74	7.6	168.6	382.3	66	6.3	169.7	291.3	62	5.6	157.0	249.3	
	Feb 21	86	9.5	152.2	534.5	70	7.0	44.2	335.5					
	Feb 23	89	10.0	39.4	573.9	76	8.0	73.2	408.7	64	6.0	22.4	271.7	
	Feb 27	99	11.6	150.3	724.2	76	8.0	0	408.7	64	6.0	0	271.7	
	Mar 8	102	12.0	50.3	774.5									
	Mar 31													
	Averaged to Feb. 27 (in^2/day)				45.2				25.5				16.9	29.2

TABLE D-1 (cont.)

CRYOPILE NO.	DATE	TOP (1)	TOP (2)	TOP (3)	TOP (4)	MIDDLE (1)	MIDDLE (2)	MIDDLE (3)	MIDDLE (4)	BOTTOM (1)	BOTTOM (2)	BOTTOM (3)	BOTTOM (4)	MEAN (IN^2/DAY)
#6	Feb 15	56	4.7	193.7	193.7	49	3.6	136.0	136.0	40	2.2	71.6	71.6	
	Feb 19	72	7.2	163.1	356.8	66	6.3	155.3	291.3	60	5.4	159.8	231.4	
	Feb 21	78	8.2	71.1	427.9	67	6.4	9.9	301.2					
	Feb 23	80	8.6	27.7	455.6	70	7.0	34.3	335.5	60	5.4	0	231.4	
	Feb 27	99	11.6	268.6	724.2	88	9.8	225.2	560.7	60	5.4	0	231.4	
	Mar 8	100	11.7	14.9	739.1				570.9[e]			11.7[e]	233.1[e]	
	Mar 31	109	13.2	156.6	895.6	90	10.2	35.3	596.0	64	6.0	40.2	271.6	
	Averaged to Feb. 27 (in^2/day)				42.6				33				14	29.8
#7	Feb 23	33	1.0	31.1	31.1	30	0.6	16.5	16.5	30	0.6	16.5	16.5	
	Mar 8	68	6.6	280.2	311.3	40	2.2	55.1	71.6	40	2.2	55.1	71.6	
	Mar 31	64	6.0			53	4.2	94.9	166.5	26	0	0	0	
	Averaged to Mar. 8 (in^2/day)				19				5				5	10
#8	Feb 23	44	2.8	98.8	98.8	40	2.2	71.6	71.6	32	0.9	26.6	26.6	
	Feb 27	57	4.8	103.4	202.2	43	2.6	20.7	92.3	39	2.0	39.1	65.7	
	Mar 8	68	6.6	109.1	311.3					40	2.2	5.9	71.6	
	Mar 31													
	Averaged to Mar. 8 (in^2/day)				13				6				5	8



CRYOPILE Nº 1 (DIESEL)

CRYOPILE Nº 2 (DIESEL)

CRYOPILE Nº 5 (DIESEL)

CRYOPILE Nº 6 (DIESEL)

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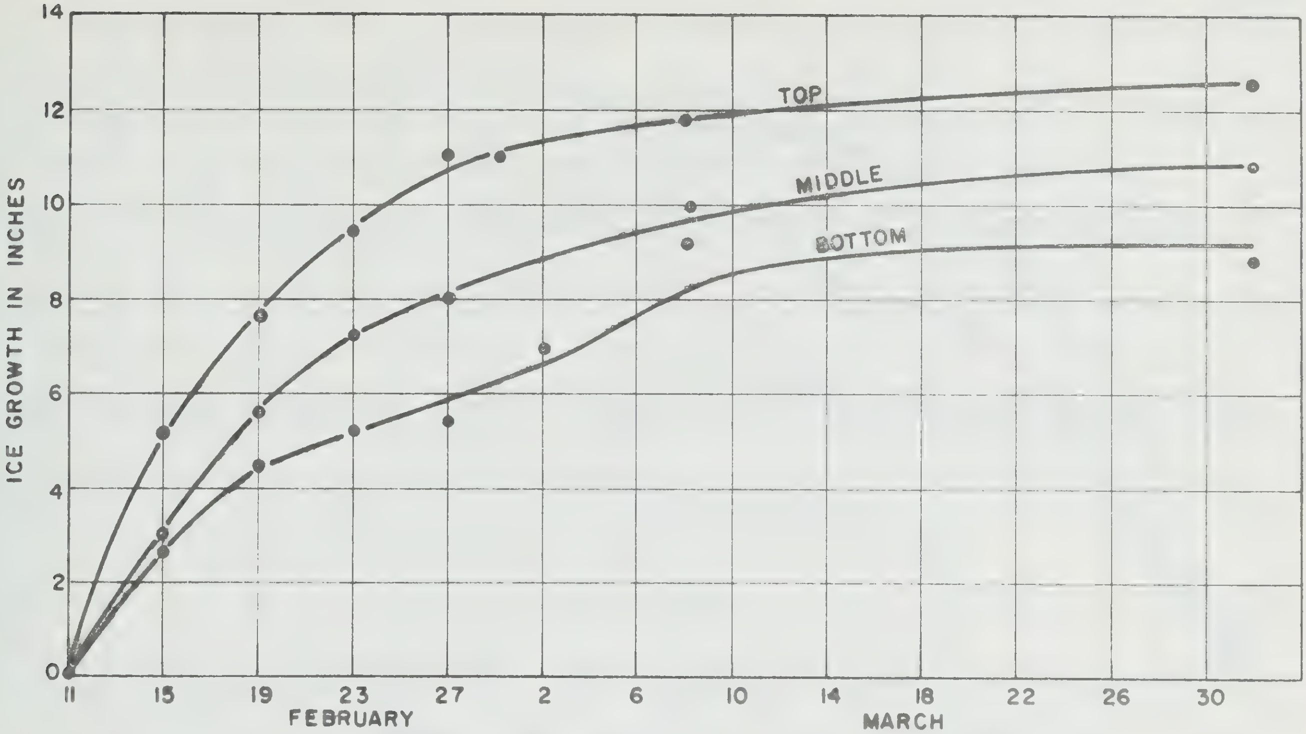
ICE DAM EXPERIMENT

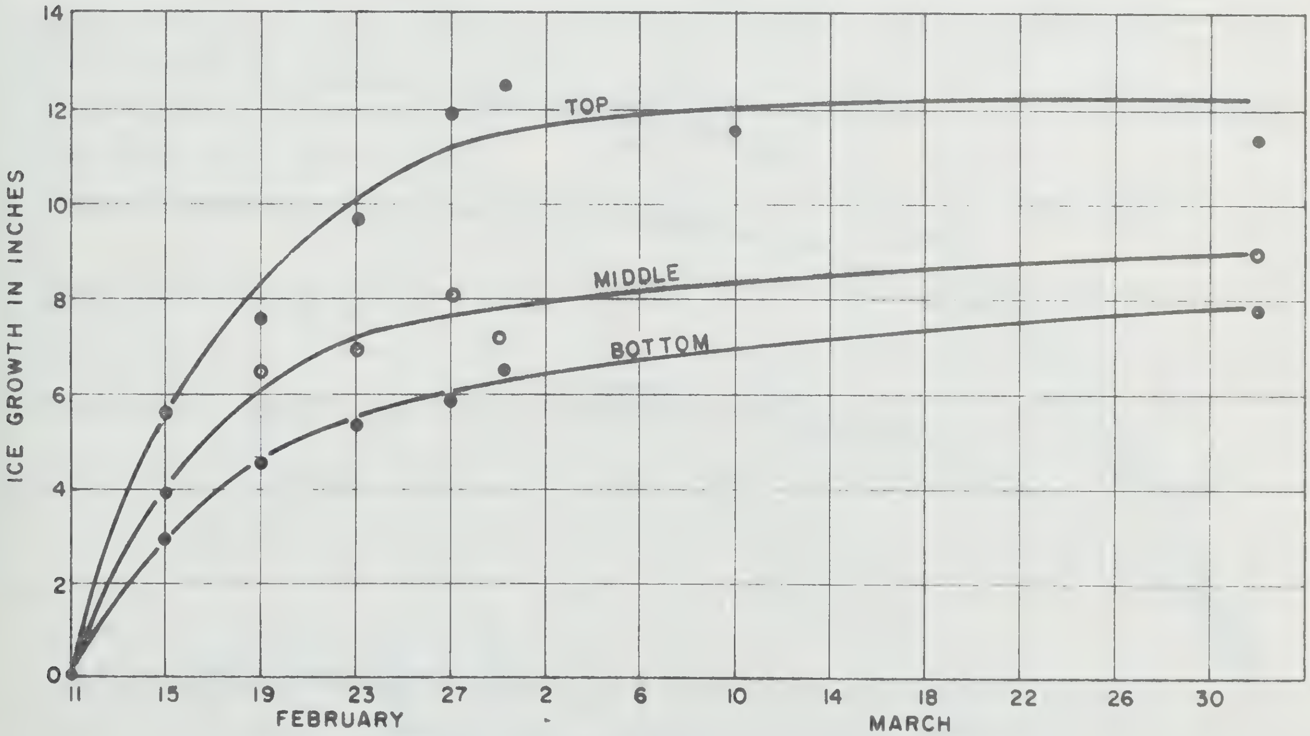
FORT CHIPEWYAN

ICE PROFILES AROUND CRYOPILES

PLATE D-3



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 1 — DIESEL OIL



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 2 — DIESEL OIL

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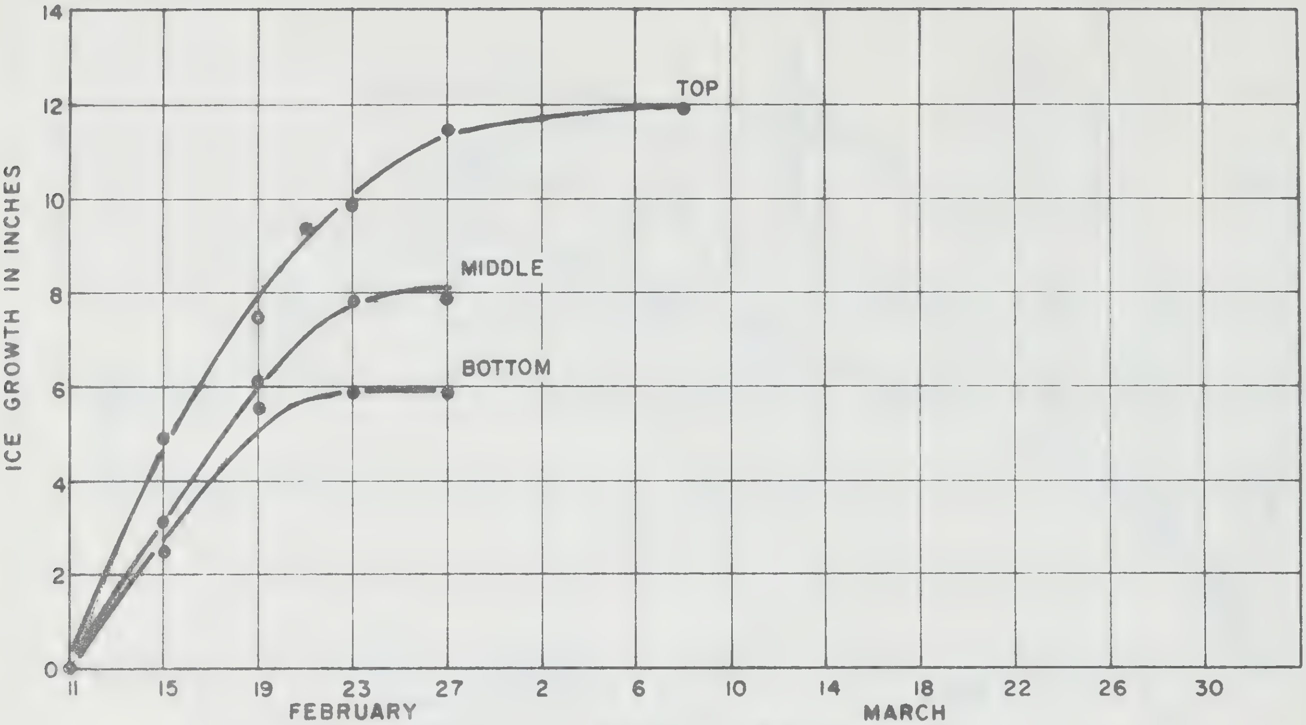
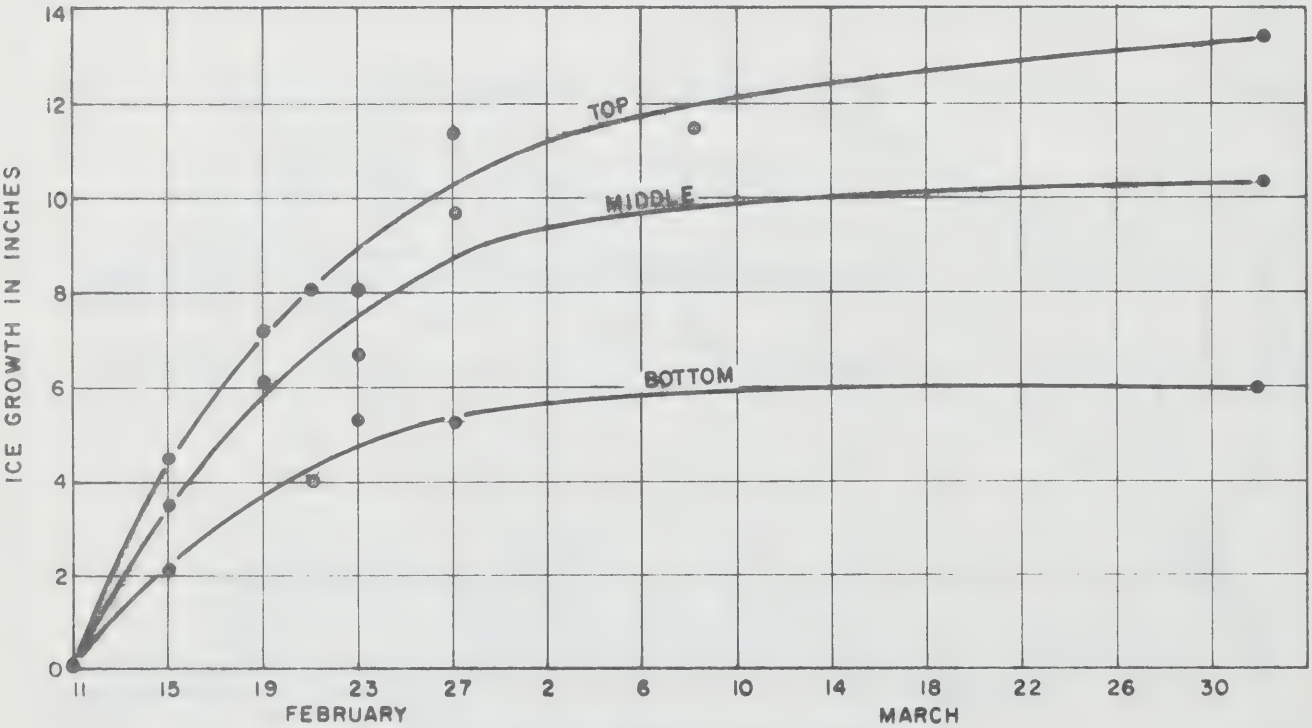
ICE DAM PROJECT
CRYOPILE EXPERIMENTS
PLATE D-4



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 5 — DIESEL OIL



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 6 — DIESEL OIL

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ICE DAM PROJECT
CRYOPILE EXPERIMENTS
PLATE D-4

direction, square inches of ice growth between measurements, rate of ice growth in square inches per day between measurements, an average rate of ice growth at the three levels taken over a long period of time, and an average rate of ice growth for the entire cryopile. Ice growth measurements were obtained at three different levels along the submerged portion of the cryopile (i.e. bottom, middle and top). In general the depth of cryopile beneath the surface was twenty feet, which included two - three feet of river ice and one foot penetration of the cryopile into the river bottom silt.

Measurement of ice growth necessitated divers going into the river to measure the circumferences of the ice mass around the cryopiles at the three different levels. It was assumed, and it certainly appears that the ice mass formed a perfect circular cylinder so that circumferences were easily converted to diameters. Some of the measurements did not seem consistent with what was expected and so were eliminated from consideration. Because of the difficult working conditions in obtaining ice growth measurements, it was to be expected that some errors would occur.

Water temperatures in the channel were a fraction above 32^{o}F, and as pointed out previously, air temperatures were fairly consistent up to March 11th, so one wouldn't expect a decrease in the amount of ice around a cryopile during this period, provided the cryopile itself wasn't interfered with. Therefore any measurements indicating loss of ice were not considered correct.

<u>Cryopiles Containing Diesel Oil</u>

These were numbered 1, 2, 5 and 6. Plate D3 provides an idea of what the ice

surface profiles looked like as the ice grew outward. Plates D4 are plots of ice thicknesses versus time and after studying the information it was decided to eliminate the following data because of probable errors in field measurements.

Cryopile	Dates of Probable Incorrect Measurements at Some Level		
1	Feb. 17	Feb. 21	March 10
2	Feb. 17	Feb. 21	March 8
5	Feb. 17	Feb. 21 (B)	March 8 (B)
6	Feb. 17	Feb. 21 (B)	March 8 (B)

(B) - Bottom measurement only

Errors were consistent over the entire ice column on February 17th, 23rd, and March 8th while errors on the remaining days occurred at only one level. However, enough correct data is available to estimate the general performance curve for each cryopile. Discounting the points in apparent error, a solid line has been drawn through the remaining points and provides an acceptable estimate of ice growth rates around each cryopile.

The following points regarding the diesel-filled cryopiles are consistent:

1. Ice growth occurs at a larger rate near the top, a lesser rate at the middle, and at the least rate near the bottom, resulting in a conical shaped ice mass.
2. The ice columns merged into the underside of the channel ice with a curved arch of about one foot radius.
3. Plots of ice thickness with time (Plate D4) show that ice growth was quite rapid in the first two weeks and then tapered off exponentially.

Rate of Ice Growth at Top of Cryopile (Diesel)

Cryopile No.	Time Interval (day) vs. Ice Growth (in./day)			
	(Feb. 11-15)	(Feb. 16-23)	(Feb. 24-29)	Mar. 1-10)
1	1.30	.54	.25	0
2	1.40	.69	.46	0
5	1.25	.84	.26	.04
6	1.12	.58	.56	.03

Rate of Ice Growth at Middle of Cryopile

1	.75	.52	.22	--
2	1.00	.37	.17	.10
5	.80	.57	0	--
6	.84	.41	0	--

Rate of Ice Growth at Bottom of Cryopile

1	.67	.30	--	--
2	.72	.30	.20	--
5	.62	.55	0	0
6	.52	.40	0	0

4. The top thickness of ice reached a limiting or steady-state value of twelve inches after about three weeks. Similar limiting values for the middle and bottom were eight-nine inches and five-six inches respectively.

5. Average ice production rates (taken from Table D1) for the diesel cryopiles were as follows:

Cryopile No.	Square Inches per Day (Horizontal Section)			
	Top	Middle	Bottom	Mean
1	40.0	25.0	12.5	25.8
2	43.2	23.0	16.4	27.5
5	45.0	25.0	17.0	29.2
6	42.6	39.0	14.0	29.8
Mean	42.7	26.5	15.0	28.1

All of the above cryopiles performed quite consistently. Even No. 6 was not affected by the fact that about one-third of its diesel oil leaked out. This

might indicate that the cryopile need not extend an equal length above the ice surface. Also the above values have assumed that the ice build-up had reached a very small rate by February 29, or sixteen days after they had been installed.

Plates A19 to A38 are photographs of the cryopiles as they were being pulled out. The ice formed appears to be uniformly circular around the cryopiles.

Cryopiles Containing Freon 12

These were numbered 3, 4, 7, and 8 and were initially charged with 290 pounds, 290 pounds, and 100 pounds of liquid Freon 12 respectively.

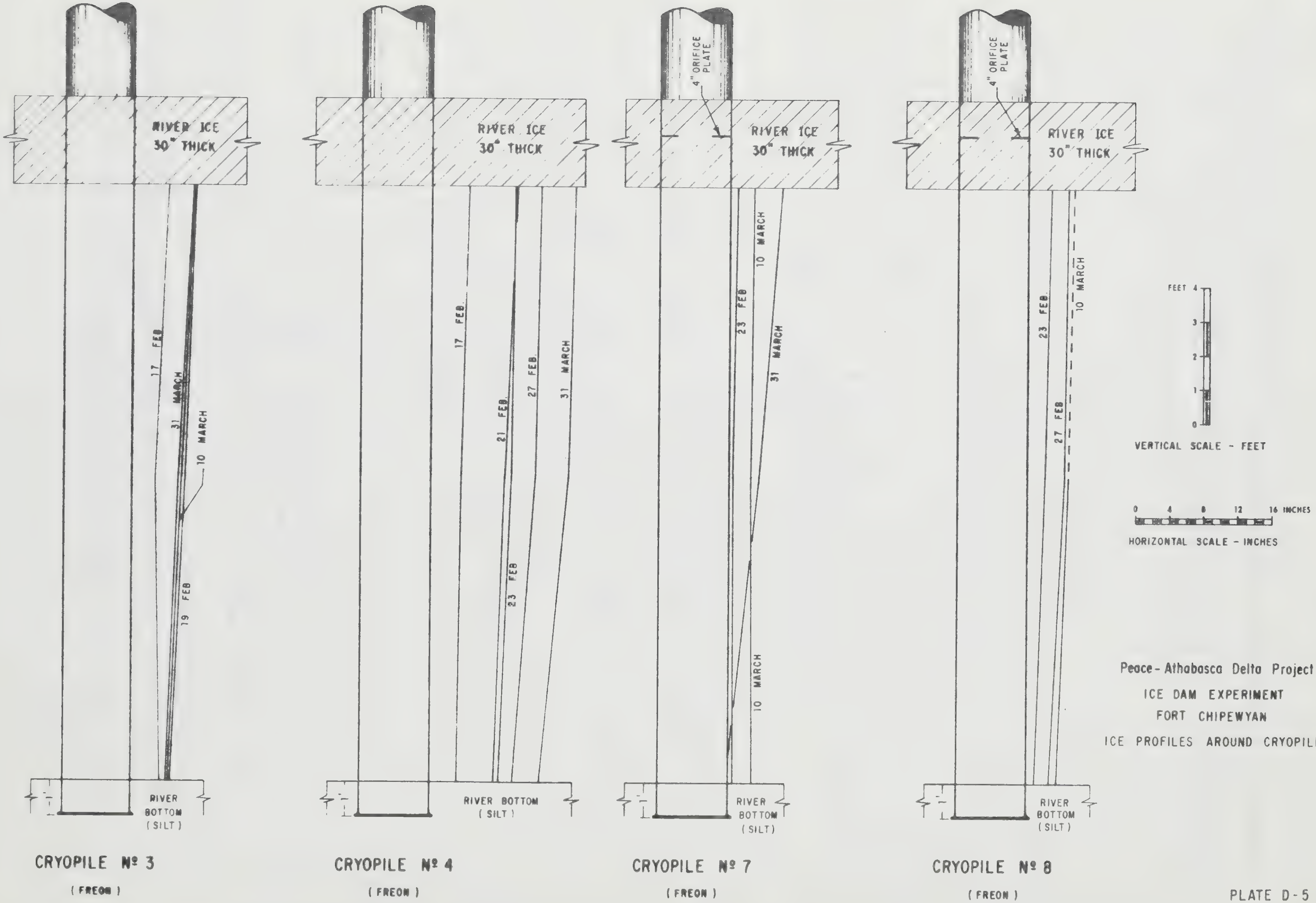
In reviewing the results, and as was done with the results from the diesel cryopiles, it was found necessary to eliminate some of the readings which appeared to be obviously in error. Following is a summary of those measurements which it was felt could be eliminated.

Cryopile	Dates of Probable Incorrect Measurements at Same Level
3	Feb. 17 Feb. 21 (B) Feb 23 Feb. 27 Feb 29 (T) Mar. 8
4	Feb. 17 Feb. 19 March 10
7	March 10
8	March 10

(B) - Bottom measurement only
(T) - Top measurement only

The performance of No. 3 was obviously dismal. It became apparent after a week or so that a slow leak had developed in the cryopile which had permitted the freon to escape into the atmosphere. Ice growth did not appreciably increase after February 19th or four days after the freon was

placed in the cryopile. Plate D5 shows the results of ice profile measurements, while Plates D6 are plots of ice growth versus time.



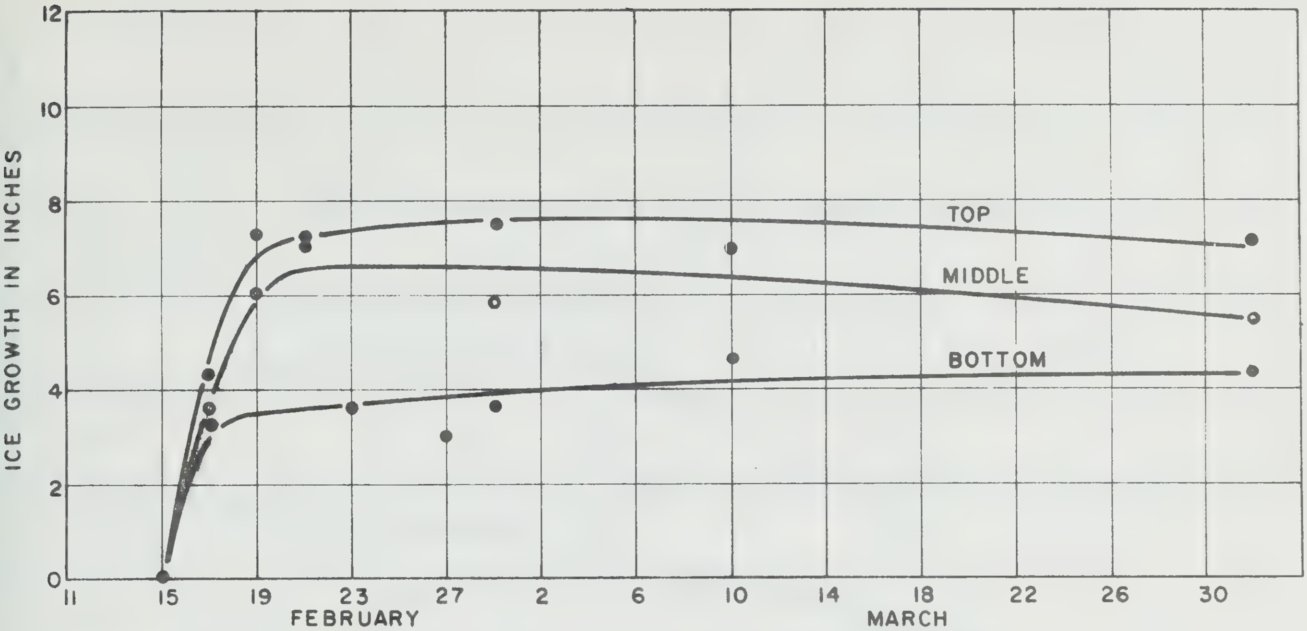
Peace-Athabasca Delta Project

ICE DAM EXPERIMENT

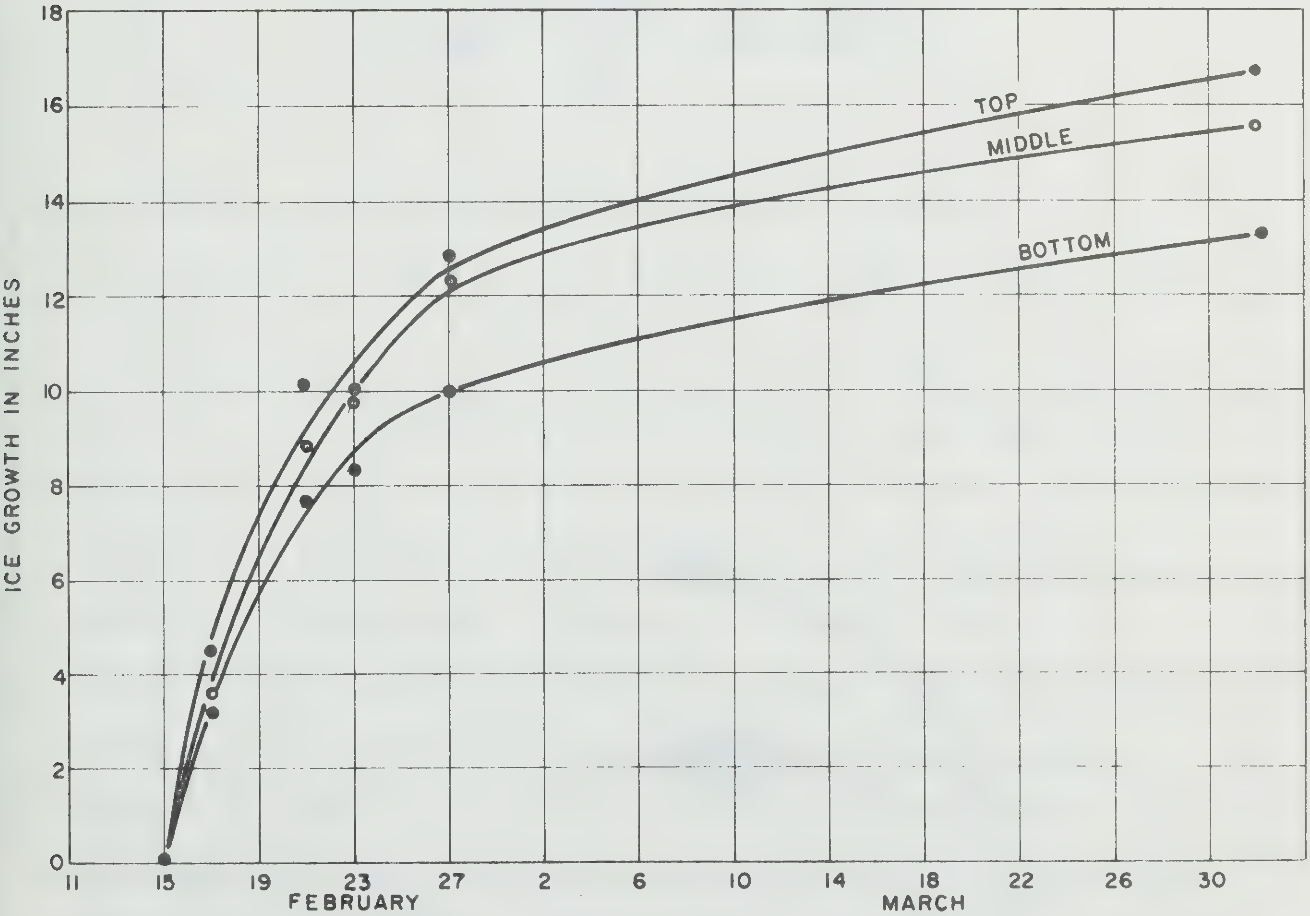
FORT CHIPEWYAN

ICE PROFILES AROUND CRYOPILES

PLATE D-5

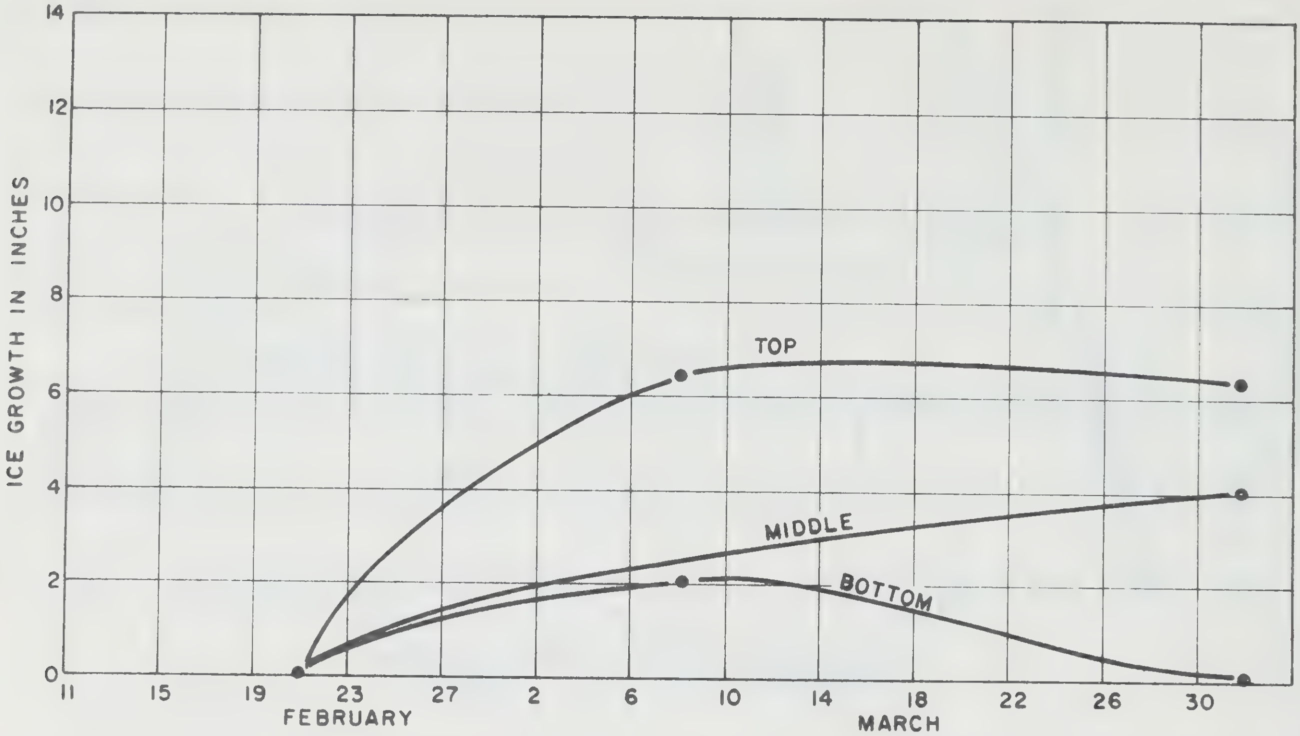


RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 3 — FREON 12

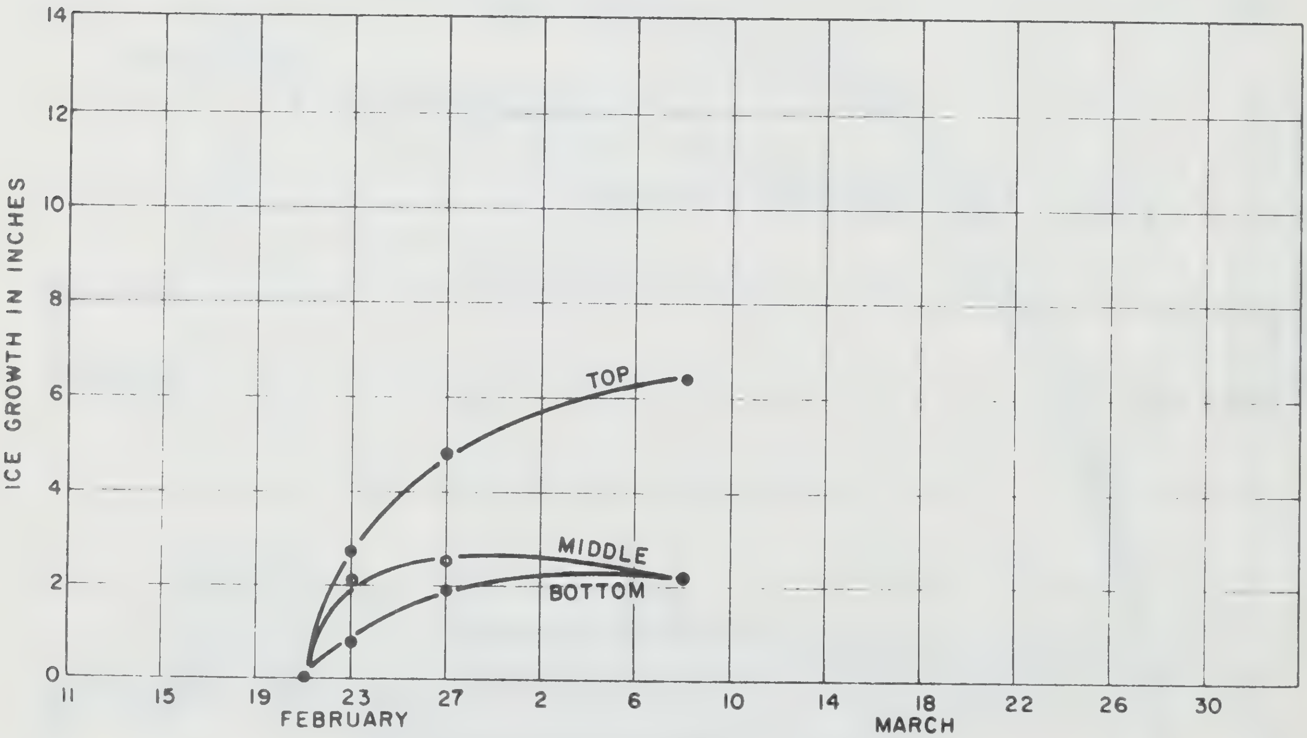


RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 4 — FREON 12

PEACE-ATHABASCA DELTA PROJECT
ICE DAM PROJECT
CRYOPILE EXPERIMENTS
PLATE - D6



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 7 — FREON 12



RADIAL ICE GROWTH VERSUS DAYS
CRYOPILE No. 8 — FREON 12

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ICE DAM PROJECT
CRYOPILE EXPERIMENTS
PLATE - D-6

Rate of Ice Growth at Top of Cryopile (Freon 12)

Cryopile No.	Time Interval vs. Ice Growth (days) (in./day)		
	(Feb. 15-21)	(Feb. 22-Mar. 8)	(Mar. 9-Mar. 31)
3	1.22	0	0
4	1.68	.22	.17
	(Feb. 21-23)	(Feb. 24-Mar. 8)	(Mar. 9-31)
7	.45	0.40	0
8	1.35	0.27	0

Rate of Ice Growth at Middle of Cryopile

3	1.20	0	0
4	1.50	.2	0
*7	.25	.11	0
*8	1.00	0	0

Rate of Ice Growth at Bottom of Cryopile

3	--	0	0
4	1.3	.15	--
*7	.25	.12	--
*8	.40	.10	--

* 7-8 same time interval as for top measurements above.

Cryopile No. 4 performed the most satisfactorily, with an ultimate ice thickness of seventeeninches at the top. Although the rate of ice produced at the top was greater than further down, in the early stages, the ice thickness eventually became uniform over the whole length of submerged cryopile. It is difficult to prove from the measurements but a few inches of ice developed quite rapidly after March 8th because the pressure was reduced in all cryopiles on March 9th. By bleeding off freon

and reducing the internal pressure it was felt that the freon would have gotten into a two phase vapour - liquid (boiling) mode. In this state the heat transfer qualities are supposed to improve. However, the lower pressure could not be maintained probably because the vapor phase was in a closed system and thus increased the gas pressure after a time. The pressure was bled off a number of times in order to maintain it at about five p.s.i. and it was during this period that a few additional inches of ice grew on Cryopile 4.

Pressure reduction in Nos. 7 and 8 did not appear to have any desirable effect on the amount of ice formed. Although these two cryopiles both produced about the same volume of ice, their performance was very much less than No. 4. Again the ice formed in a conical fashion on Nos. 7 and 8, with a curved transition into the channel ice.

Overall ice production rates for the freon cryopiles were as follows:

Cryopile No.	* Square Inches Per Day (Horizontal Section)			
	Top	Middle	Bottom	Mean
3	-	-	-	-
4 (To Feb.27)	67	63	45	58
7 (To Mar.8)	19	5	5	10
8 (To Mar.8)	19	6	5	10

It appears that Cryopile 4 was two to three times better at producing ice than any of the diesel units while the diesel units were about three times better than Cryopiles 7 or 8 which contained lesser amounts of freon and also included an orifice plate which was supposed to help control the movement of vapour and condensed freon within the cryopile. It is quite

likely that the orifices were of limited help because the freon was not in the vapour phase, at least until March 9th when pressures were reduced Also, it appears that the amount of freon used has a significant influence on the performance, with ice forming efficiencies varying with the amount of freon.

Circulating Diesel

This system has been described previously and in general it involved cutting down Cryopile 3, filling it with diesel oil, draining the diesel into a tank and then recirculating it down to the bottom of the cryopile through a two inch pipe placed within the cryopile. However, after operating this system for a day or two it became obvious that the pump was adding substantial amounts of thermal energy to the circulating diesel. The result was a melting of the ice near the top of the cryopile. The system was shut-down and could not be revamped because of moderating air temperatures. Hindsight suggests that the pump should have been placed between the cryopile and the inlet to the tank and diesel should have been fed back into the cryopile by gravity. Also the discharge lines from the tank should have been longer or the tank larger in order to ensure complete cooling of the diesel before it went back into the cryopile.

It is also interesting to note that the freezing process extended down into the channel bottom silt. When the cryopiles were pulled out there remained a frozen bulb of silt on the end and this can be observed in Plates A23, A24, and A29 to A32.

Experimental Ice Plots

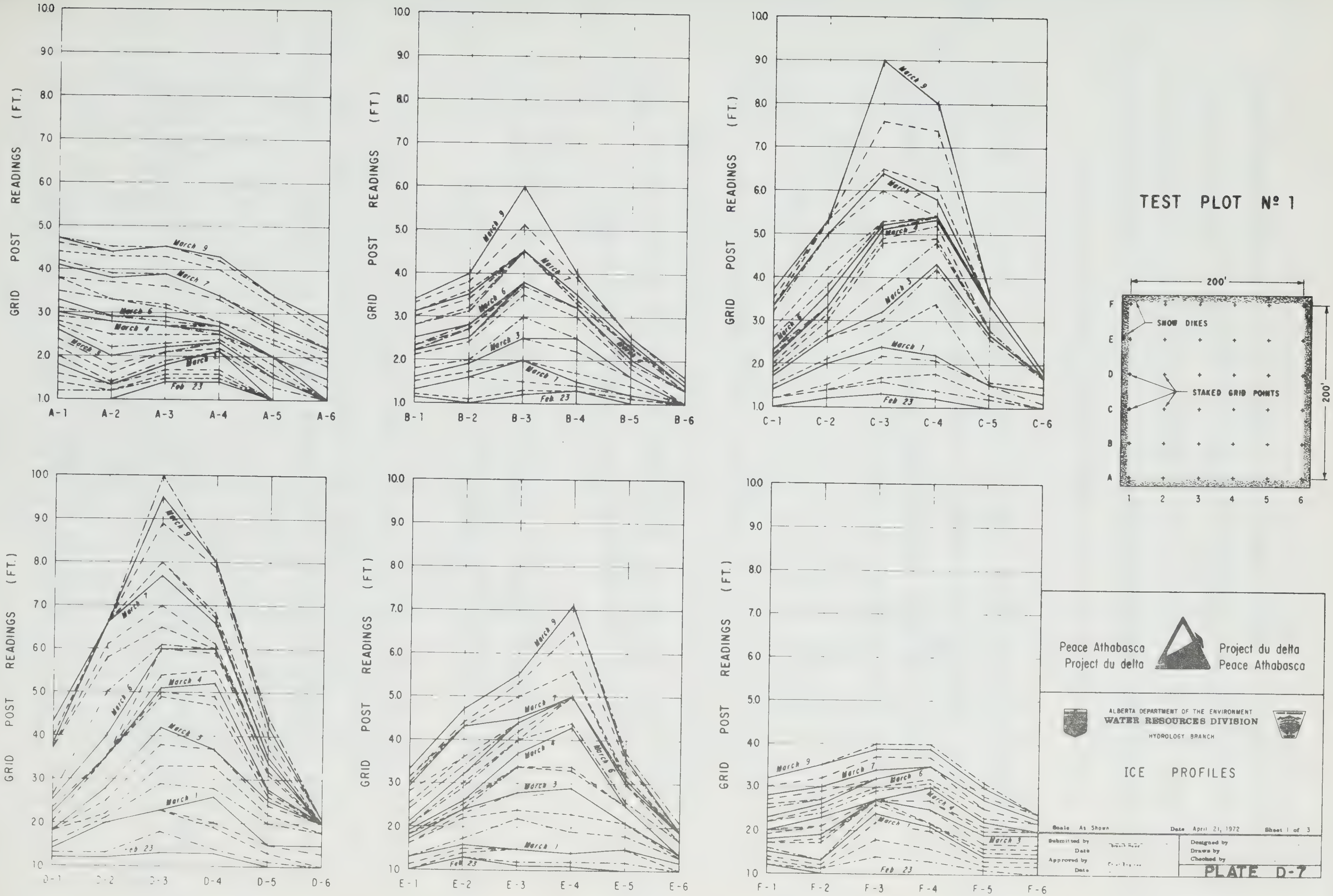
The primary purpose of this aspect of the operations at Fort Chipewyan was to lay down as much ice as possible over a given area, using two methods of water distribution, i.e. sprinklers, and flooding procedures as utilized in the construction of ice bridges. Secondary to this objective was to establish what some of the technical problems might be in operating certain mechanical devices (pumps, sprinklers) under extreme cold temperature conditions. The physical setup of the ice plots has been described in Appendix C and it remains to present and discuss the results.

Test Plot 1

The Buckner sprinklers purchased for the experiments were constructed in California and not really designed for cold temperature operation. Water pumped through the sprinklers taken from the Rochers River channel was near freezing so that any additional small amount of heat loss would freeze it. Thus water in transit from the discharge end of the pump to the sprinkler nozzles had to travel two hundred feet through aluminum pipe with air temperatures reaching $-30^{o}F$, with the net result that water would gradually freeze up in the pipe. Plates A45 to A48 amply demonstrate the final product of water freezing in the discharge line.

Heat tapes and insulation were installed on the aluminum pipes, which eliminated the freezing up problems, and Plates A46 and A50 show this system in operation.

TEST PLOT Nº 1



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WATER RESOURCES DIVISION
HYDROLOGY BRANCH

ICE PROFILES

Scale At Shown | Date April 21, 1972 | Sheet 1 of 3

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PLATE D-7

The sprinklers included a mechanical system to rotate them automatically but this didn't work, primarily because the rotational mechanism on each sprinkler would freeze up. Also it would have been more appropriate to use a very light grease or perhaps no lubricant at all in the main bearing. As it was, the sprinklers were turned manually every few minutes.

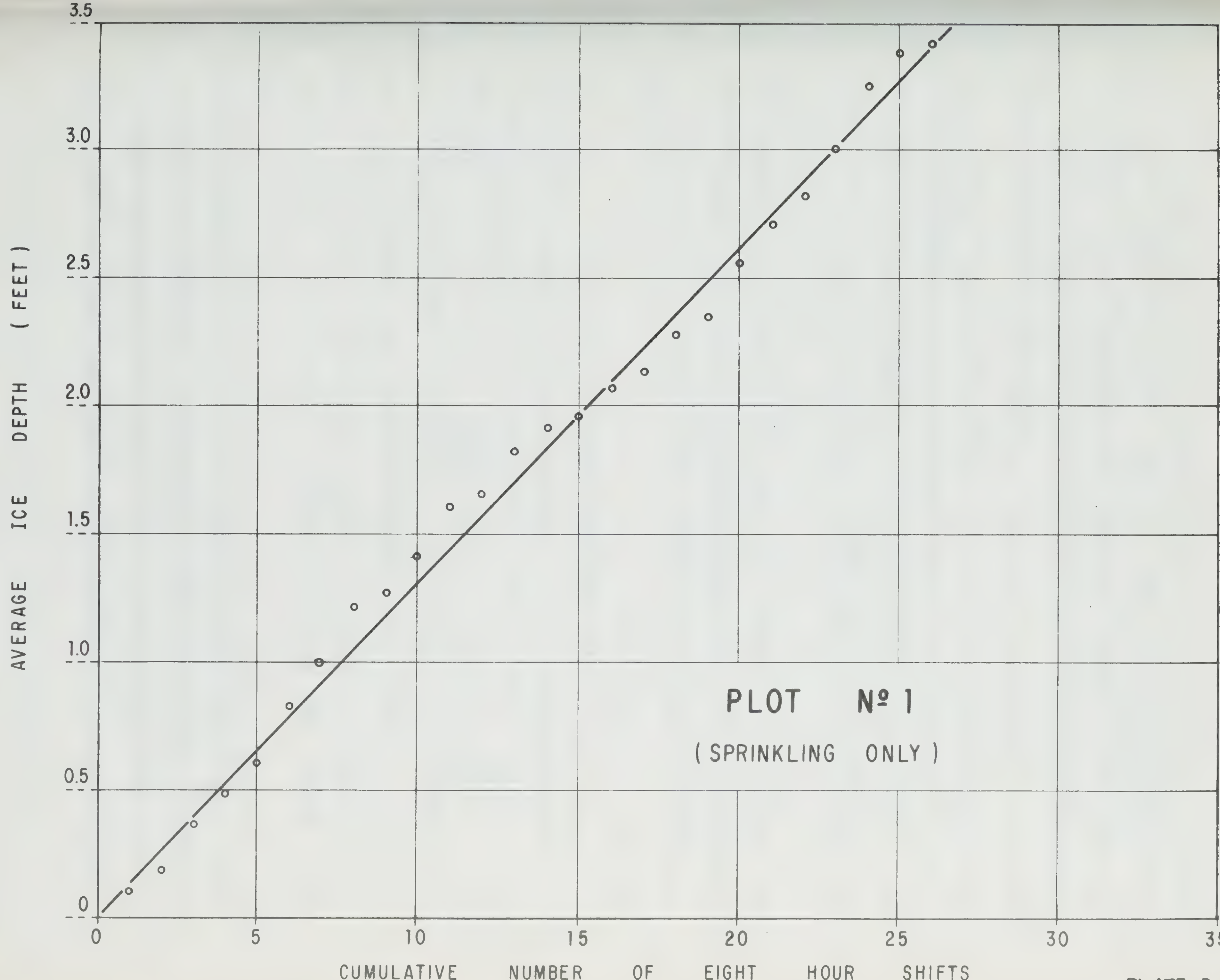
The sprinkler on Test Plot 1 was originally turned on February 16th but because of the freeze-up problems, it didn't function uniformly until February 29th. Operation was for eight hours a day only until February 29th, after which operation was extended to sixteen or twenty-four hour periods.

Plate D7 shows the time-wise profiles of ice accumulation on Test Plot 1. Ice accumulation readings from the grid markers were read after each eight hour shift so that any difference between one profile and the next one above indicates the amount of ice build-up in eight hours.

This data has been averaged to provide Plate D8 which shows average depth of built-up ice versus cumulative number of eight hour shifts.

The average rate of ice build-up per eight hour shift is given by the slope of a best-fit line through the points and is thus 1.57 inches per shift or 4.71 inches per day. This would require .35 acre-feet of water per day, or 60 IGPM.

Since the discharge could not be varied, it can't directly be concluded



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
AVERAGE ICE DEPTH (FEET)
0
5
10
15
20
25
30
35
CUMULATIVE NUMBER OF EIGHT HOUR SHIFTS
PLOT Nº 1
(SPRINKLING ONLY)

PLATE D-8

whether or not the rate of ice build-up could be substantially greater if a larger pump were used, but it is likely. Most of the water from a sprinkler froze in the air or on impact with the ground so that it was not often that water accumulated on the test plot because of excess water and too small a freezing rate. Therefore it is conceivable that by using a sprinkler which could have a variable trajectory and adjustable nozzle sizes, one could use a pump of much higher capacity and produce more ice. Siz e of water drops and time in air could then be adjusted in order to produce freezing upon impact of the water with the ground.

This ability to vary trajectory and nozzle size is important in producing a high density ice. Density measurements as outlined in the following table indicate what problems could arise through improper operation of a sprinkler. It is noted that

Ice Densities - Test Plot 1

Grid Point Location	Density (lb./ft^3)	Comments
E2	55.88	Sample Int. 0'-1'
D5	51.21	" 0'-1'
C3	28.43	" 0'-1'
C3	31.25	" 3'-4'
Average	41.69	

Note: Natural river ice 60.39 lbs./ft^3

densities vary from 28 lbs/ft^3 to 58 lbs./ft^3. The latter values would be adequate but the lower one would be unacceptable. Plate A66 shows one of the areas where the low density ice was formed, and in fact the substance shown is more akin to being packed snow rather than ice. This is the

result of a fine spray from one of the nozzles and the effect is what one would expect from a snow machine. Although, as shown in Plate A65, the volume of this ice-snow was large in some places, the kind of material formed might not be satisfactory.

Vertical Movement

Vertical movement of the ice mass on Test Plot 1 was checked by taking level readings on reference markers. The amount of downward movement of ice would be a function of the ice density and the sheer strength of the adjacent and underlying river ice. For Test Plot 1 the ice mass is estimated to have sunk 2.52 feet and this can be compared to the average build-up from sprinkling of 3.42 feet. Therefore the ratio of vertical drop to ice build-up is 0.74.

Test Plot 3

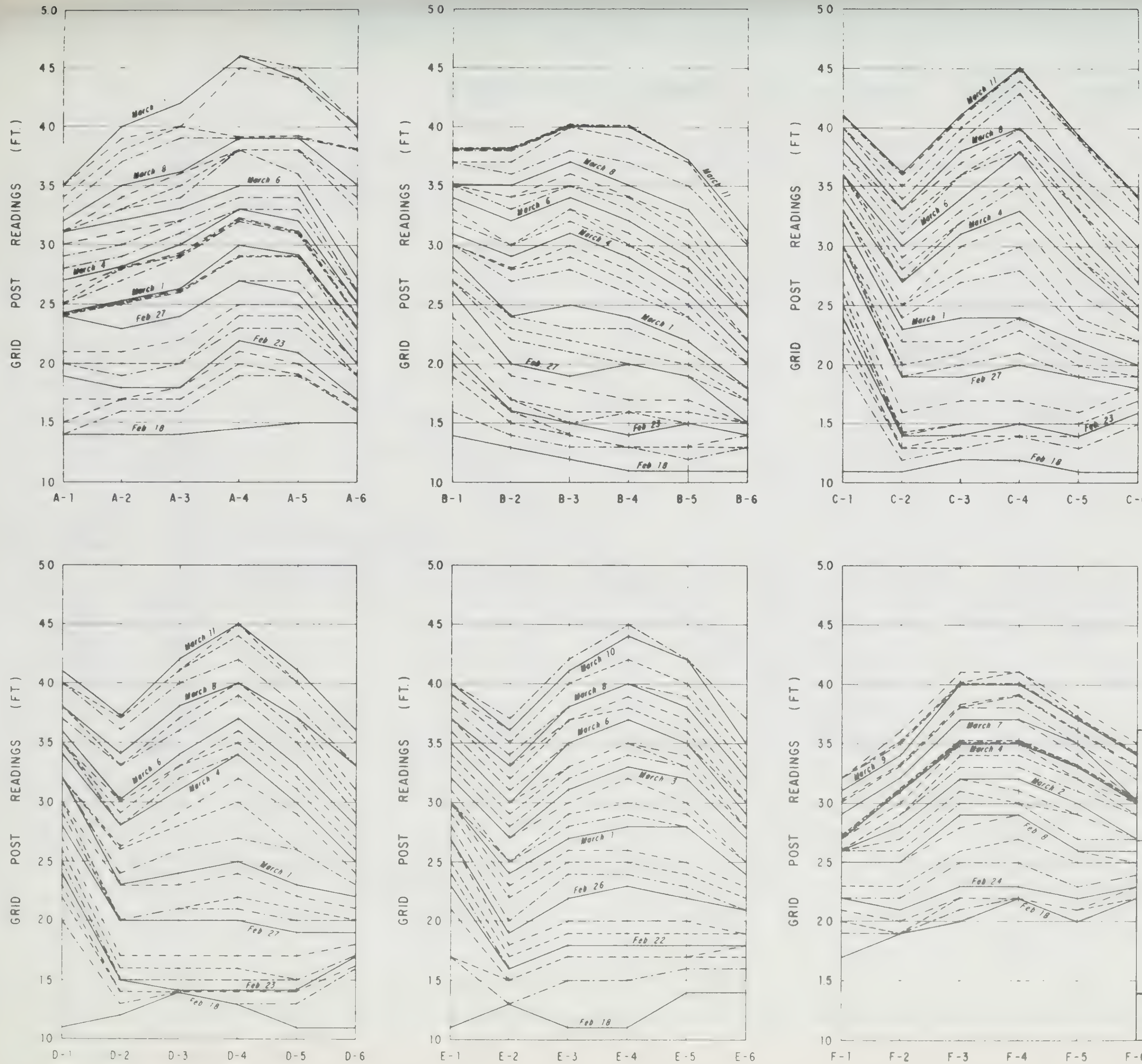
Flooding commenced on February 16th with one layer of water being put down in an eight hour shift. Until February 29th, technical problems with the low head pump permitted only one layer of water to be flooded per day. Ice accumulation was recorded at the end of every eight hour working period and results are recorded with respect to "shifts", so that results from Test Plot 1 could be directly compared.

Plate A57 shows the flooding procedure in progress, with water being discharged at one point in the plot and being permitted to find its own level and spread over the entire plot. Problems were encountered with the leaking dikes shown in the background of Plate A57. The procedures

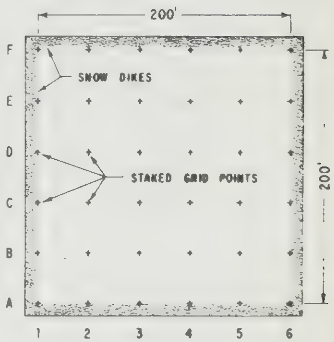
employed differed from normal ice bridge construction, primarily with respect to the size of pump used. A six inch pump was employed and proved to be too large for the amount of water required, but on the other hand its size permitted a greater amount of durability for continuous operation. Normal ice-bridge construction practices require small two-inch pumps to be used so that they can be moved from place to place on skids or a small truck. The last few flooding lifts were made using a two-inch gasoline driven pump and the field crew found the procedure very satisfactory because hoses could be moved about and drained easily, and water could be placed where it was thought most necessary. However, this pump malfunctioned after a few days, and it was generally felt that electric driven pumps would have been more superior provided electric power was available.

Plate D10 is a plot of ice accumulation versus flooding frequency. It was normally found that the full eight hours was required for any particular amount of water flooded, to adequately freeze. The average rate of ice accumulation or the slope of a best-fit line on Plate D10 is 1.13 inches per eight hour shift or 3.38 inches per day. This would require .24 acre-feet of water per day applied at a rate of 3 cfs three times a day for an hour each time assuming three lifts a day are made.

This rate of ice accumulation should be considered to be near a maximum value whereas the value derived from Plot 1 could potentially be greater if certain adjustments were made in the system of sprinkling used.



TEST PLOT Nº 3



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ICE PROFILES

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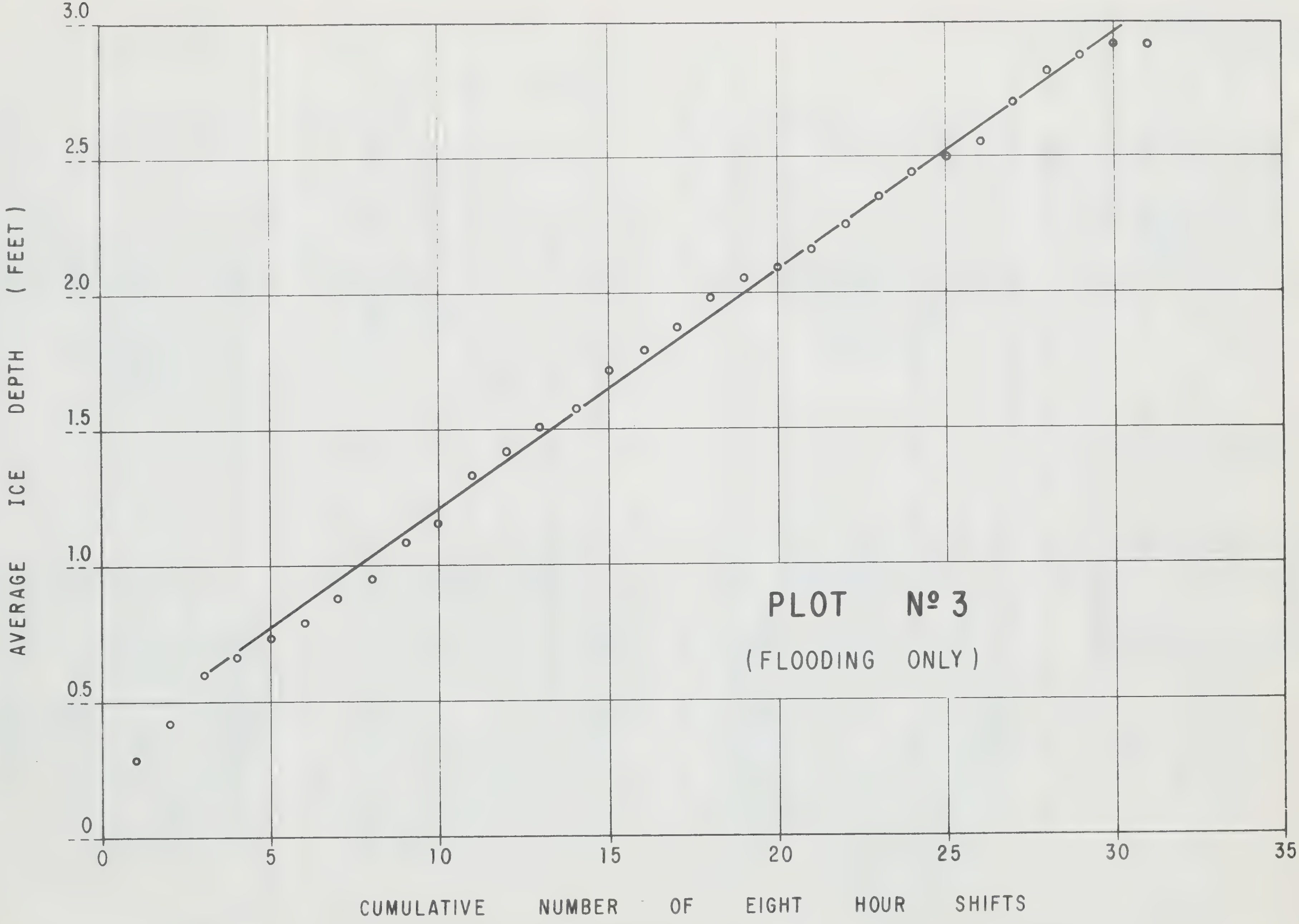
Designed by / Drawn by / Checked by

PLATE D-9


PLOT Nº 3
(FLOODING ONLY)
AVERAGE ICE DEPTH (FEET)
CUMULATIVE NUMBER OF EIGHT HOUR SHIFTS
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
25
30
35

Ice densities (see following table) were on the average higher than those achieved for Test Plot 1. Plates A60 and A61 show examples of the ice made and densities varied from 53.9 lbs/ft^3 to 56.8 lbs/ft^3, which values could be considered quite satisfactory.

The ice mass sunk down on the average 2.34 feet with an average build-up of 2.91 feet. Ratio of vertical drop to ice build-up is 0.80 which when compared to this ratio from Test Plot 1 confirms the higher density of ice in Test Plot 3. This factor is important when deciding on which system (i.e. sprinkling or flooding) would be better. On the one hand the ice accumulation rate is 38 per cent higher for sprinkling but the densities from flooding were 10 per cent higher. If the densities achieved from sprinkling could be increased, sprinkling would appear to be the more satisfactory method of the two.

Ice accumulation profiles are given in Plate D9, which is a summary of ice build-up at the end of every eight hour period.

Ice Densities - Test Plot 3

Grid Point Location	Density (lb/ft^3)	Comments	
D3	53.89	Sample Int.	0'-2'
B2	55.46	"	0'-1'
B2	57.31	"	1'-2'
B2	56.60	"	3'-4'
C5	52.63	"	0'-1'
C5	54.45	"	1.5'-2.5'
C5	49.33	"	3'-4'
E4	54.60	"	1'-2'
E4	56.30	"	1.5'-2.5'
E4	56.77	"	3.5'-4.5'
Average	54.73		

Test Plot 2

This ice build-up site was originally intended to combine flooding and sprinkling to see if the two could be a compatible operation. Unfortunately, serious freeze-up problems were encountered with the sprinkling system and it was abandoned.

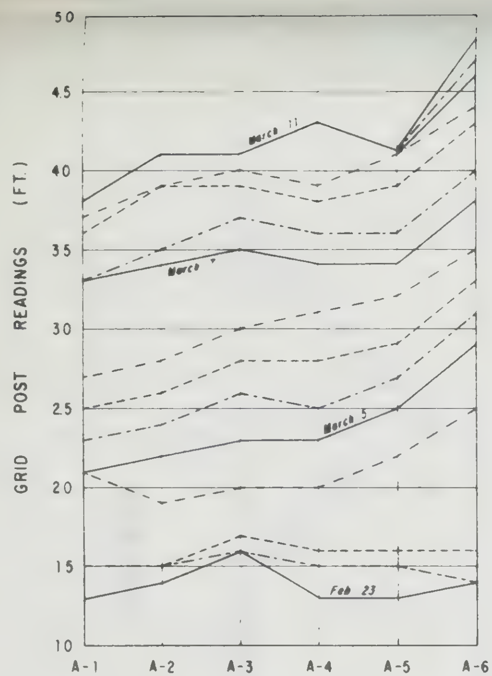
Sprinkling commenced on February 16th and ended on March 1st, and included only five separate shifts of ice making. Plate D11 provides the ice accumulation measurements at the end of any eight hour ice making period, in the form of ice profiles along various grid lines. Plate D12 is a plot of ice accumulation versus cumulative number of eight hour shifts. The average rate of build-up for the sprinkling portion of the plotted values is 1.50 inches per shift or 4.4 inches per day, which is similar to the average value obtained for Test Plot 1. For the flooding portion of this plot the average rate of ice accumulation was 1.26 inches per shift or 3.78 inches per day. This value is higher than that obtained on Test Plot 3 and must be considered a limiting value.

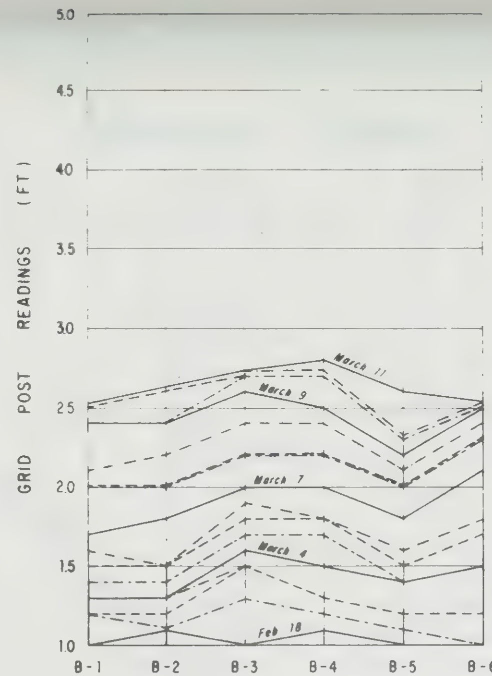
Ice density values measured were as follows:

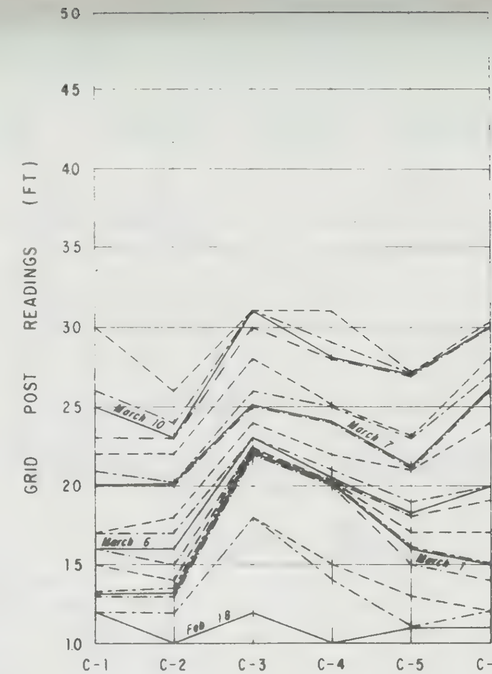
Ice Densities - Test Plot 2

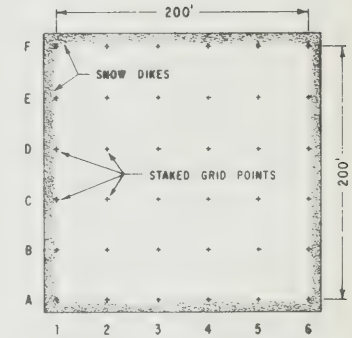
Grid Point Location	Density (lbs/ft^3)	Comments	
D3	52.38	Sample Int.	0'-1'
D3	55.84	"	1.5'-2.5'
D3	59.40	"	3'-4'
E5	55.23	"	0'-1'
E5	55.61	"	1'-2'
B5	53.78	"	0'-1'
B5	53.40	"	3'-4'
B2	56.18	"	0'-1'
B2	52.90	"	2.5'-3.5'
Average	54.97		

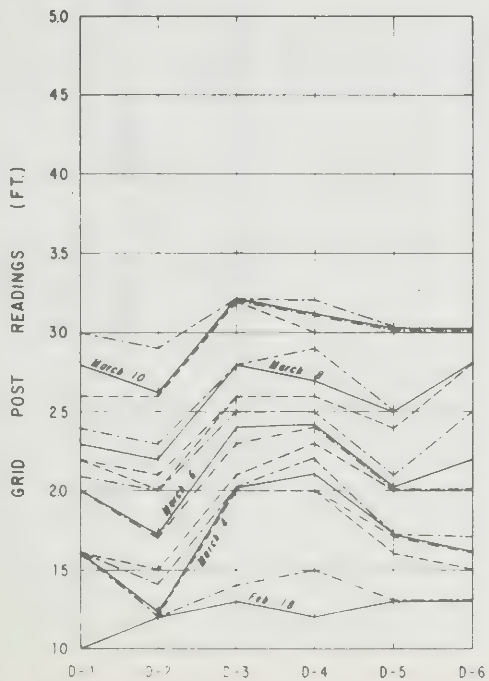
TEST PLOT Nº 2

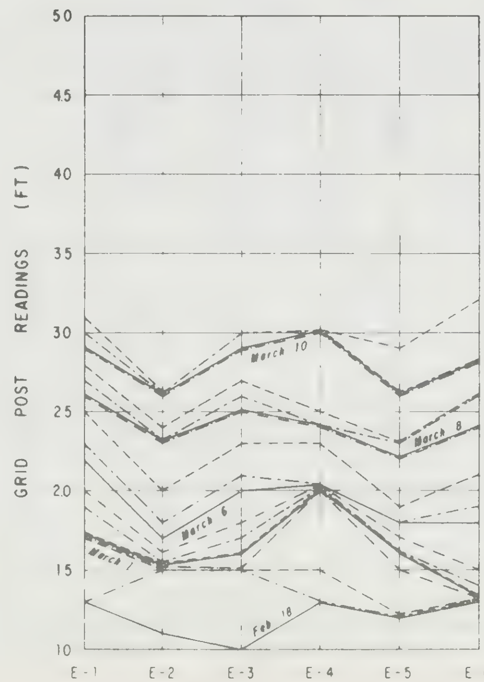


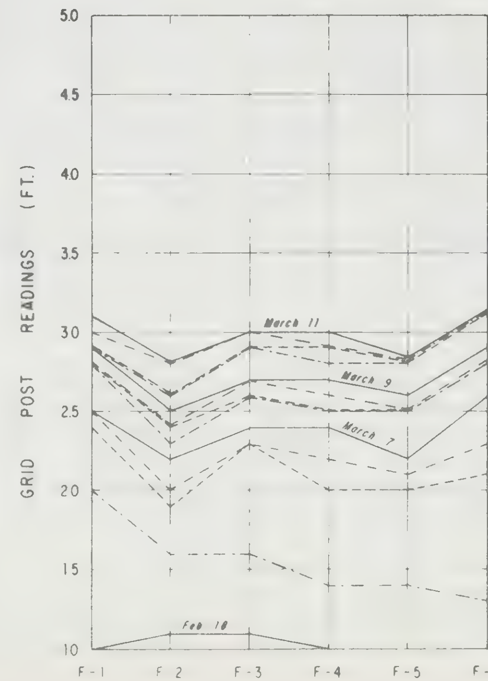












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ICE PROFILES

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PLATE D-11

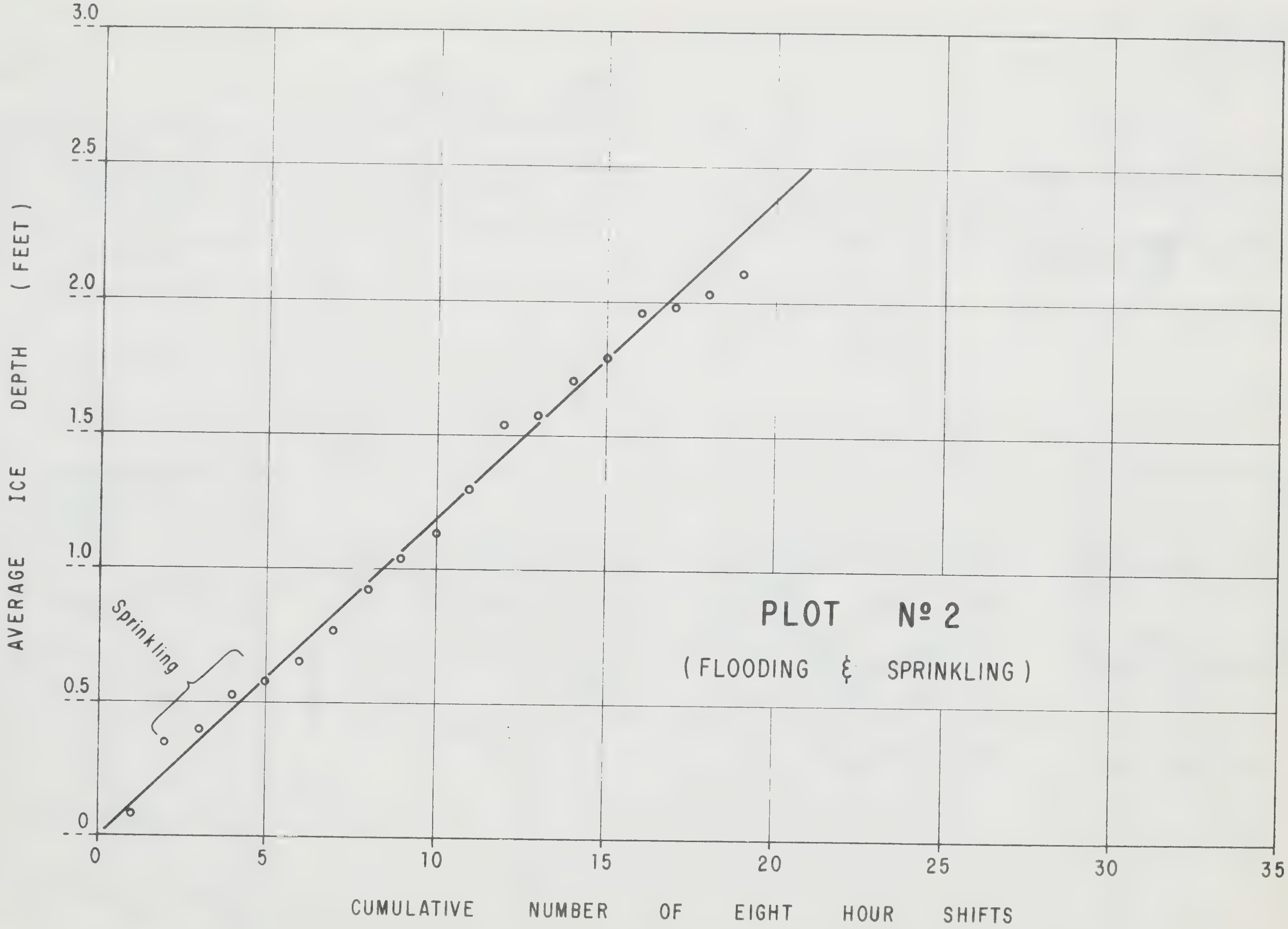
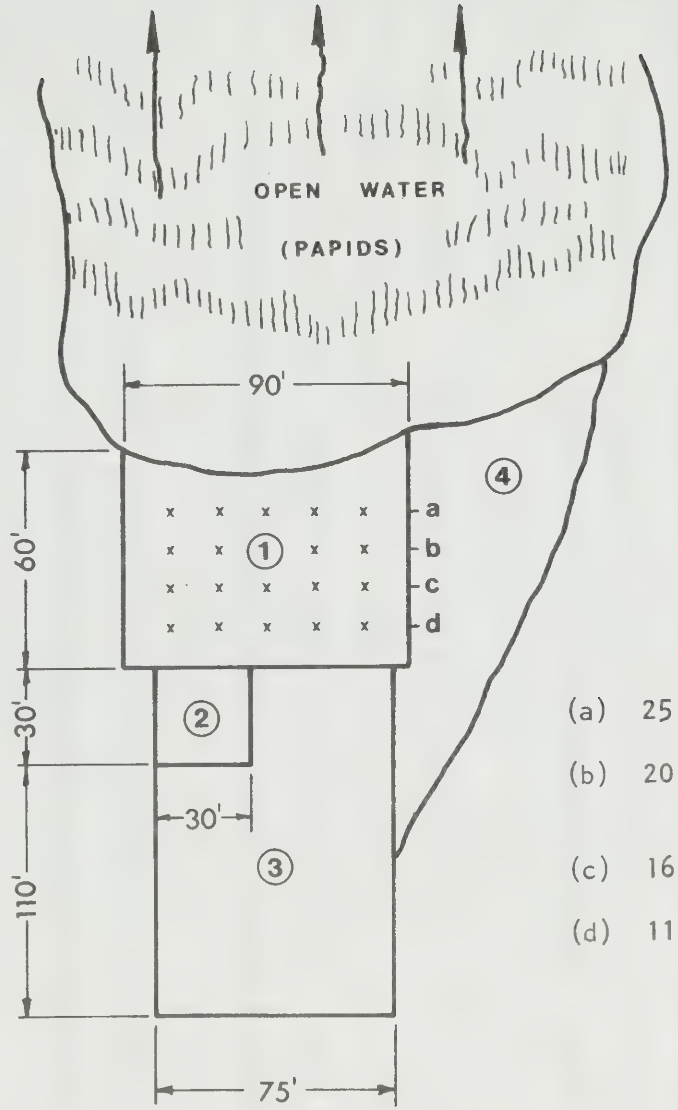

PLOT Nº 2
(FLOODING & SPRINKLING)
Sprinkling
AVERAGE ICE DEPTH (FEET)
CUMULATIVE NUMBER OF EIGHT HOUR SHIFTS
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
25
30
35

PLATE D-12



Charge 1

(a) 25 charges - 2 lb. = 50 lbs. dynamite

(b) 20 charges - 10 x 2 lb.
- 10 x 2.5 lb. = 45 lbs. dynamite

(c) 16 charges - 2 1/2 lb. = 40 lbs. dynamite

(d) 11 charges - 2 1/2 lb. = 27 1/2 lbs. dynamite

Total - 162 1/2 lbs.

The above charges were placed throughout area indicated at about 10' to 20' centres. Ice near water was about four inches thick, increasing to two feet at back of blast area.

Plate A69 shows the charges being placed, while Plate A70 shows the blast occurring. Plates A71 to A75 show the sequel to the blast. Most of the ice in the blast area was crushed into small pieces (up to two feet in size). Larger floes (10' to 15' in size) broke off around the edges of the open water (see Plate A72). Some of the thinner ice floes were drawn under the river ice downstream. Plate A74 shows the larger ice floes being drawn under the ice cover.

Explosion No.2 was carried out on February 20, 1972. Plate D13 shows the area where the charges were placed. Size of charges varied from 2½ to 3 lbs., with a total of 44 lbs. of dynamite placed around the periphery of Blast Area No. 2, with one 3 lb. charge in the centre.

Plate A76 shows the charges going off with the result that many very small ice floes formed with no large sizes (see Plate A77).

Explosion No. 3 was carried out on February 22, 1972. Plate D13 shows the area in which the charges were set. Twenty-nine one pound charges were laid around the periphery at about 3 yd. intervals. Plate A78 shows these charges going off with Plates A79 and A80 showing the result.

Many larger floes (10' x 30') and many smaller ones (2' to 3') developed

with very little crushed ice showing up. Ice thickness varied from 23" to 28". Very few of the ice floes were pulled under the ice cover.

Explosion No. 4 was carried out on February 22, 1972. A total of 25½ lbs. of dynamite were set in 3½ lbs. to 5 lb charges around the periphery of the area shown in Plate D13. Due to a misfire only one five pound charge exploded (see Plate A81), with the result that one large (10' x 30') ice floe broke away (Plate A82). This ice floe did not go under the downstream ice cover.

Explosion No. 5 merely involved setting a forty pound charge of dynamite in a surface, whereas all of the previous charges were set down into the ice (see Plate D13). The result was a hole in the ice and no ice floes produced.

Plate A84 shows the final result after five settings of dynamite charges. Most of any ice floes which did get pulled under the ice cover, did so after Explosion 1. The first two sets of charges were too large because only small bits of ice blocks resulted. The smaller charge in Explosion 3 produced some reasonably large sized ice blocks.

<u>Lambton Park Experiments (Edmonton)</u>

The operation of the experimental set-up shown in Plate A3 did not produce very satisfactory results. However, some of the observations are presented for interest sake.

When water was placed in the storage tanks its temperature was approximately 47°F. Therefore before any ice could begin forming on the cryopiles, the water had to be cooled considerably and it took about one week to get the water to a near freezing state.

The six inch steel cryopile was charged with 290 pounds of Freon 12 on February 8th, while the six inch aluminum cryopile was filled with Kerosene on the same day. Both storage tanks were filled with water on February 9th. The kerosene cryopile was abandoned on February 23rd, when it was discovered that the refrigerant had leaked out. Because kerosene is a lighter fluid than water the level of kerosene in the cryopile drained to a height about five feet above the ice level in the tank. Removal of the cryopile to repair the leak would have been impossible.

By February 12th water temperatures in the freon tank had decreased to about 35°F near the bottom, 43°F at mid-level and 46°F at the top. On February 14th, a circulation pipe froze up causing it to break open and allow one-third of the water to drain out of each tank. At this point, one inch of ice had built up on the cryopile containing freon. Refilling of the tank with warm water brought up the water temperatures and caused a good portion of the cryopile ice to melt.

By February 19th temperatures within the tank had decreased to a fraction of a degree above freezing. However, constantly freezing circulation lines necessitated that the space heater within the shelter be operated and this added heat to the water in the tank. The result was an increase in

the water temperature.

The first ice measurement was taken on February 23rd and the amounts of radial ice growth around the freon cryopile were as follows (ice thickness):

Top - 3.48", Middle - 4.26", Bottom - 0'

It is impossible to estimate exactly when the ice growth began but it is likely that on February 19th when water temperatures in the tank reached a near freezing state, ice growth was rapid from that point. Therefore, a very rough estimate is .87 in. per day at the top and 1.06 in. per day at the centre of the cryopile. These values compare roughly with the results from the first few days of the freon cryopiles (No. 4) in the Fort Chipewyan experiments.

It is interesting to note that no ice formed near the bottom of the cryopile. This can be attributed to the heat input at the bottom of the tank by the circulation system. The large pump used to circulate water added heat to the water, which dissipated soon after re-entering the tank near the bottom. Temperature measurements did indicate that temperatures were in general a bit higher near the bottom.

It became evident soon after these first measurements that a stable thermodynamic condition did not exist within the tank and the cryopile, which made any results obtained doubtful as to their applicability in a field situation. This all came about primarily because of; (1) the varying and unknown amount of B.T.U.'s added by the circulating pump,

(2) the varying and unknown amounts of BTU's added through the tank walls by the space heater which had to be used to keep circulating lines open, and (3) solar radiation which seemed to have some affect on the internal cryopile temperatures as was evident by the widely varying vapour pressures observed.

APPENDIX E

PRELIMINARY REPORT ON HYDRAULIC MODEL TESTS
PROPOSED RIVIÈRE DES ROCHERS ICE DAM

INTRODUCTION

The office of the Peace-Athabasca Delta Project is considering a proposal whereby a temporary ice dam would be created at the Rivière des Rochers rapids in order to raise water levels in Lake Athabasca. In this proposal, cryopiles would be used to narrow the width of the flow channel about 200 feet; then this gap would be plugged by causing a hanging ice dam to form.

The material for the hanging dam would be generated by blasting the ice cover on Rivière des Rochers upstream of the rapids. The resulting ice flow would be carried downstream by the flow, through the gap and under the downstream ice cover. It would 'deposit' under the ice cover at some point where the flow velocity is low. (Forcing all of the discharge through a 200 foot gap will create a flow jet which will carry quite far downstream. It will diffuse with distance, spreading and decreasing in velocity.) As more and more material is carried under the ice cover, a 'hanging dam' will form, which would lengthen, spread and deepen. Given enough material, such a hanging dam may deepen sufficiently to jam to the bed, thus damming the channel.

A hydraulic model study was authorized by the Delta Project to check the reasoning concerning the development of the hanging dam and to assist in estimating the volume and size of material required. It was also looked

upon as a means of gaining insight by allowing visualization of the phenomenon. The study was carried out in The Graduate Hydraulics Laboratory of the University of Alberta by personnel of the University. Design and supervision of the model and the interpretation of results were carried out by T. Blench and Associates Limited, Consulting Hydraulic Engineers.

REFERENCE DATA FOR THE MODEL STUDY

Many of the conditions that will exist at the site at the time of closure cannot be predicted, but inasmuch as certain data were required as input to the model study, some assumptions had to be made and given as instructions for the model study by the Delta Project office. These included:

1. The cryopiles will narrow the channel to a 200 foot gap.
2. The first flow condition to be modelled:
   a. Rivière des Rochers discharge: 20,000 cfs.
   b. Lake Level: 680 feet.
   c. Drop from the lake to the rapids: 2.0 feet.
   d. Drop across the rapids: 1.5 feet.
   e. Model tailwater (Water surface elevation downstream of the rapids): 676.5 feet; tailwater rating curve not defined.
3. Thickness of upstream ice cover (source of material for hanging dam):
   a. Initial assumption 2.0 feet; modified after the section model tests to 1.0 foot.
4. Continuous rate of blasting of the upstream ice cover of 4200 yds/hr, bulk measure. This is equivalent to blasting 57,500 ft^2 per hour or one 4 ft x 4 ft block per second if the ice is 1 ft thick, or 29,000 ft^2 or one 4 ft x 4 ft block per 2 seconds if 2 ft thick.
5. 4 ft by 4 ft blocks will not break up when subjected to flow forces when they are carried under the downstream ice cover and deposited in the hanging dam.
6. Downstream ice cover (under which the hanging dam will form) not artificially thickened in the model.
7. Inerodible channel bottom.

THE MODEL

The study was conducted as a Froude Law model; i.e. the Froude Number ratio between model and prototype was one. The tests were carried out to a scale of 1:100 in a section model built in a plastic-sided flume 18 inches wide by 20 feet long. This type of model was chosen because it minimized the amount of model ice material required and it allowed inspection of the bottom surface of the hanging dam. A scale of 1:100 was chosen so that the model ice material prepared would be usable if the study were transferred to the comprehensive model at the University's Ellerslie River Engineering Building. Other model scales were: velocity, 1:10; time, 1:10; discharge, 1:100,000 and volume, 1:1,000,000.

The longitudinal section of the rapids was reproduced and the flow constricted from one side, leaving a gap of about one-fifth the width of the flume, which approximately represented the proposed prototype condition where the 1000 foot wide channel will be restricted to 200 feet. The correct model unit discharge was established and the cross section of the rapids adjusted to obtain a 1.5 foot drop. After the flow conditions were set, a surface dam was introduced about 1000 feet downstream to prevent loss of model ice material.

MODEL TECHNIQUE

The model ice, low density polyethylene (specific gravity 0.92), was introduced upstream at the assumed rate. The first portion floated through the gap and downstream until it was stopped by the surface dam. This continued until an ice cover consisting of a single layer of particles formed between the surface dam and the rapids. Material subsequently injected was carried under this ice cover and deposited, starting a hanging dam. This process continued, with observations being made and data photos taken at regular intervals, until either the test was aborted or until closure was accomplished. An increase in water surface elevation upstream of the rapids indicated that closure was being effected. When this was observed the discharge in the model was decreased in accordance with the assumption that the discharge in Rivière des Rochers varies directly as the square root of the difference in water levels between the lake and a point just upstream of the rapids.

TESTS

1. Section model; 20,000 cfs; 4 ft x 4 ft x 2 ft blocks; 4200 yds/hr; self-formed ice cover.

    a. Photos 1 and 2; 7000 yds after formation of ice cover.

    The hanging dam started forming 400 feet downstream from the rapids on the same side of the flume as the gap. The black line in the photos indicates the deepest part of the dam. (The quantity given above--7000 yds--is a three-dimensional-prototype equivalent in

terms of the volume of the dam; includes interstices.)

b. Photos 3 and 4; 35,000 yds after formation of ice cover.

The hanging dam grew upstream, spread to the right and deepened. The flow jet issuing from the gap was spread and deflected to the right by the dam.

c. Photos 5 and 6; 63,000 yds after formation of ice cover.

The dam continued to grow upstream, to spread to the left and to deepen. Some blocks were jammed to the bed on the left side of the dam. The jet was sharply deflected to the right. No increase in upstream water surface elevation was observed.

d. Photos 7 and 8; 98,000 yds after formation of ice cover.

Closure complete. The discharge was reduced to 18,500 cfs. Limited compressive failure (buckling) of the downstream ice cover occurred as a result of the thrust on the ice dam. The permeability of the dam seemed too large, as indicated by the large discharge passing through the dam at the time of closure. Inasmuch as the dam at the site will probably plug with small pieces of ice and frazil, the headloss and thrust in the model were unrealistically low.

3. Section model; 20,000 cfs; 4 ft x 4 ft x 2 ft blocks plus granulated polyethylene (approximately cylindrical, 1 ft diameter by 1 ft long; added to decrease permeability); 4200 yds/hr; self-formed ice cover. Photos will be included in the final report.

After the ice cover was formed out of 4 ft x 4 ft x 2 ft blocks, a mixture of blocks and granulated material was injected continuously at

the above rate. The hanging dam started to develop in much the same way as in Test 1, spreading almost across the flume and jamming to the bed in places after 28,000 yds of mixture had been added. A check accomplished by injecting dye into the dam indicated that the granulated material was effective in reducing permeability. Shortly after this point in the test, the upstream level started rising and compressive failure of the downstream ice cover began. The decreased permeability apparently caused greater headloss and hence an increase in thrust on the dam. As the buckling occurred the dam drifted downstream, and even doubling the injection rate did not advance the closure. After about 150,000 yds were added, the test was aborted.

3. Section model; 20,000 cfs; 4 ft x 4 ft x 2 ft blocks plus granulated polyethylene; 4200 yds/hr; rigid downstream ice cover starting 300 feet from the rapids. Photos will be included in final report.

   It was thought that the self-formed particulate ice cover was too susceptible to compressive failure, although such failure may occur at the site as a result of the combination of uplift force due to the buoyancy of the hanging dam and the thrust on the dam. A model test was undertaken in which a rigid downstream ice sheet represented by a sheet of polyethylene was introduced in order to observe the formation of the hanging dam when compressive failure was not a factor.

   The hanging dam started to form immediately when the mixture of blocks and granulated material was injected and developed in a similar fashion to the dams of Tests 1 and 2. At 35,000 yds, the first blocks jammed to the bed. At 50,000 yds the upstream water surface started rising. At 105,000 yds closure occurred; no downstream movement of the dam was

observed.

CONCLUSIONS

1. For the conditions set out for the study, the model indicated that a hanging dam will form and jam to the bed.
2. Some analysis has to be carried out regarding the likelihood of compressive failure of the downstream ice sheet. If it appears certain, some input to the model regarding the extent of such failure is required.
3. The permeability of the hanging dam in the model is important. If the permeability at the site will be near zero due to frazil ice, then the model dam must be made impermeable by the addition of suitably graded material.

RECOMMENDATIONS

1. Before the project is undertaken, it is recommended that comprehensive testing be conducted on a correctly contoured three-dimensional model. This requires a tailwater rating curve to be defined as a model input.
2. The scheme should be tested at higher discharges if it is possible that it will have to be implemented at higher discharges in the future.
3. The rate of generation of ice used in the study was very high; it is recommended that future studies be carried out at a conservatively low rate as volume of material required is partially a function of rate of feed.

APPENDIX F

RELEVANT COMMENTS ON CRYOPILE EXPERIMENTS

FORT CHIPEWYAN

1. Cryopiles 1-6 placed in river, February 11th. Filled Nos. 1, 2, 5, and 6 with diesel oil.

2. February 15th, filled Cryopiles 3, 4 with 290 lbs. of liquid Freon 12 each. Measurements on circumferences on Cryopiles 1, 2, 5 and 6 by Army.

3. February 17th, circumferences measured on all Cryopiles (by Army).

4. February 19th, circumferences measured on all Cryopiles (by Army). Placed in Cryopiles 7 and 8. Noted small leak in Cryopile 4.

5. February 21st, Cryopiles 7 and 8 charged with liquid Freon 12. Circumferences measured on Cryopiles (by Army).

6. February 23rd, circumferences measured on all Cryopiles (by Army).

7. February 28th, circumferences measured on all Cryopiles except 7.

8. February 29th, circumference measured on Cryopiles 1, 2 and 3.

9. Bled Freon 12 out of 3 in order to facilitate reconstruction of Cryopile, March 4th.

10. March 6th, constructed new Cryopile (No. 3) so that diesel oil can be pumped down center (2") pipe to bottom of Cryopile. It was thought that this would improve the heat transfer qualities of a Cryopile.

11. Bled off pressure in all Freon 12 Cryopiles to 5 psi; March 9th.

12. March 10th, pressure in Freon 12 Cryopiles back up to 18 psi, which may partially be due to the effect of solar heat. Began operating Cryopile 3. Complete circumference measurements made on Cryopiles 3, 4, 7 and 8; partial measurements on remainder.

13. March 11th, ice around Cryopile 3 is beginning to melt so it appears that the diesel being circulated is picking up a lot of B.T.U.'s from the pump. Cryopile 3 shut down.

14. March 31st, pulled all Cryopiles except 5, which broke off about four feet below the ice surface.

SUMMARY OF DAILY FIELD NOTES - FORT CHIPEWYAN ICE DAM EXPERIMENT

Date (1972)	Comments
Tues. Feb. 15	Freon 12 forced into Cryopiles 3 and 4 by means of heating up tanks with propane torch.
Wed. Feb. 16	Sprinklers on Test Plots 1 and 2 froze up because of snow and slush in lines. Impossible to prime high head pump.
Thur. Feb. 17	First flooding on Test Plot 3; 4"-6" of water in two hours.
Fri. Feb. 18	It appears low head pump too big because of inability to distribute water evenly. Extreme difficulty in priming and starting pumps.
Sat. Feb. 19	Trouble maintaining tight discharge hose due to freezing of water within hose. Lowered two Cryopiles (7 & 8) using front-end loader; worked well.
Mon. Feb. 21	Both sprinklers started. Drive to rotate them won't operate, but can be turned by hand.
Tues. Feb. 22	Sprinklers out of commission because intake hose frozen solid. Flooding of Test Plot 3 continuing.
Wed. Feb. 23	Sprinklers started up again but must continue to turn them manually. Sprinklers and lines frozen solid.
Thur. Feb. 24	Suction hoses on both pumps continue to freeze-up.
Fri. Feb. 25	Applied insulation and heat tapes to irrigation pipe.
Tues. Feb. 29	Operated sprinklers but suction hose froze up and pipe joints blew apart.
Wed. Mar. 1	Sprinkler started up on Test Plot 1, but not Test Plot 2 because too many pipes have been broken. Flooding on Test Plot 3 continuing.
Fri. Mar. 3	Irrigation pipes keep blowing apart and must be bolted together. Repairs made and sprinkler back on.
Sat. Mar. 4	Having trouble keeping water from running out of Test Plot 3.
Sun. Mar. 5	Sprinkler on Test Plot 1 continuing to run satisfactory.
Mon. Mar. 6	Continue to loose irrigation pipe and fittings because of poor connections, but sprinkler is continuing to be operated.
Tues. Mar. 7	Started flooding both Test Plot 2 and 3.

Date (1972)	Comments
Wed. Mar. 8	Flooding three times a day and sprinkler still operating.
Sun. Mar. 12	Temperatures getting too warm to make ice. Sprinkler shut down because high head pump seized.
Wed. Mar. 15	Difficulty in taking ice densities on Test Plot 1 because of water lenses (2" thick) through ice pack.
Thur. Mar. 16	Started flooding Test Plot 3 with small (2") pump rather than the large (6") pump. This worked very well.
Fri. Mar. 17	Connecting rod on 2" pump broke, flooding operation halted.

SECTION H

S E C T I O N H

THE EFFECTS OF THE W. A. C. BENNETT DAM AND THE ROCHERS WEIR ON THE SLAVE RIVER, GREAT SLAVE LAKE AND THE MACKENZIE RIVER

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Ottawa

August 1973

SECTION H

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INTRODUCTION

The flow regime of the Peace-Athabasca River System has been considerably altered since the construction of the W. A. C. Bennett Dam. The effects of this dam on downstream levels and flows were considered in an earlier study (Coulson and Adamcyk, 1969). Since the publication of that report, some more data have become available. Also, a rockfill weir on the Riviere des Rochers, the main channel connecting Lake Athabasca to the Peace River, has been proposed. In view of these considerations, the Peace-Athabasca Delta Project undertook a study to estimate the effects of these control structures on the levels of Great Slave Lake and flows of the Slave River and the Mackenzie River. This appendix presents an analysis of the data obtained by the Project. The main objective was to study the conditions during the navigation season which extends for a five-month period from June 1 to November 1. The recorded or estimated data are the mean monthly flows and the mean daily end-of-the-month lake levels for a 12-yr period of 1960 to 1971 inclusive. The results of this study may be considered of limited accuracy only because of some possible errors in the estimated data and small sample size.

EFFECTS ON THE SLAVE RIVER

Table 1 gives a comparison of the mean monthly flows of the Slave River at Fitzgerald under natural and regulated regimes. The estimates of June, peak and October flows through the full range of probabilities are given. Two conditions of regulation are: (1) the Bennett dam only and (2) the Bennett dam and the Rochers Weir.

This table shows that the effect of the Bennett Dam in reducing the natural flows in the early part of the navigation season is quite

Table 1:- Natural and Regulated Flows of the Slave River at Fitzgerald in 1000 cfs

	June			Peaks			October		
P	N	BD	BD+RW	N	BD	BD+RW	N	BD	BD+RW
.05	282	229	234	293	240	246	190	174	162
.10	275	222	226	285	232	237	182	168	157
.25	264	211	213	273	219	222	168	156	147
.50	252	199	199	260	205	204	153	143	136
.75	240	188	185	247	190	187	138	131	126
.90	230	177	172	235	177	172	125	120	116
.95	223	170	164	228	170	162	117	113	110

P = Probability of exceedance

N = Natural flows

BD = Regulation by the Bennett Dam only

BD+RW = Regulation by the Bennett Dam and the Rochers Weir

pronounced although in October the differences between the regulated and the natural flows are small. The effect of the Rochers Weir is not so clear. During the early part of the season, it appears to slightly increase the flows of low probabilities and to slightly decrease the flows of high probabilities. However, the differences are so small as to be negligible. The October flows of all probabilities are reduced by the Rochers Weir. A possible explanation is that the Weir holds back the outflow from Lake Athabasca during summer and fall months and releases it later during winter and spring months.

EFFECTS ON GREAT SLAVE LAKE

Reductions in the levels of Great Slave Lake may affect barge traffic on the upper Mackenzie River, particularly on Beaver Lake which is located at the outlet of Great Slave Lake. Although this problem is not expected to be serious, it is necessary that some estimates of the expected changes in its regime be made. Table 2 gives the estimated natural and regulated levels of Great Slave Lake at Yellowknife Bay at various probabilities.

This table shows that the effect of the Bennett Dam is to raise the Lake levels in the beginning of the navigation season. As the season progresses, the regulated level becomes less than the natural level and remains so throughout the season. The effect of the Rochers Weir is to slightly increase the levels regulated by the Bennett Dam until the middle of the season. However, in the latter part of the season, the effect of the Weir is to decrease these levels by about 0.10 foot.

The average reduction in the peaks by the Bennett Dam is about 0.5 foot. The Rochers Weir appears to have little or no effect on the regulated peaks.

In order to correctly interpret the regulation by the Bennett Dam

Table 2:- Natural and Regulated Levels of Great Slave Lake at Yellowknife Bay, ft.

	May 31			Peaks			October 31		
P	N	BD	BD+RW	N	BD	BD+RW	N	BD	BD+RW
.05	514.72	514.95	515.02	515.87	515.22	515.30	514.90	514.50	514.30
.10	514.65	514.86	514.92	515.75	515.10	515.20	514.75	514.42	514.22
.25	514.52	514.72	514.75	515.40	514.95	515.00	514.45	514.20	514.10
.50	514.32	514.50	514.55	515.25	514.80	514.82	514.15	513.95	513.85
.75	513.97	514.20	514.25	514.90	514.65	514.67	513.75	513.60	513.50
.90	513.57	513.82	513.83	514.37	513.95	513.95	513.35	513.17	513.10
.95	513.30	513.55	513.55	514.00	513.50	513.50	513.00	512.87	512.80

GSC Datum (1968). Add 0.32 foot to compute levels corresponding to previous datum.

P = Probability of exceedance

N = Natural Lake Levels

BD = Regulation by the Bennett Dam only

BD+RW = Regulation by the Bennett Dam and the Rochers Weir

with and without the Rochers Weir, it is necessary to follow the annual march of the natural and regulated Lake Levels. It may be noted that the peaks under natural and regulated conditions do not always occur in the same month. An analysis of the 12 yearly peaks revealed the following: (1) The timing of the peak was governed by the Bennett Dam only and the Weir had no effect on it: (2) natural peaks always occurred in July or August while the regulated peaks occurred in May, June or July; and (3) 6 regulated peaks occurred in the same months as natural, 4 occurred 1 month earlier and 2 occurred 2 months earlier.

Table 3 gives the 12-yr means of the natural and regulated levels of Great Slave Lake at Yellowknife Bay. It also gives the changes in levels attributable to the Bennett Dam with and without the Rochers Weir. The net effect of the Rochers Weir is also given. In general, the effect of the regulation is to decrease the levels from June to November and to increase them from December to May. The mean maximum end-of-the-month reduction due to the Bennett Dam only is 0.44 foot and with the Rochers Weir it is 0.53 foot. These reductions occur in August. The mean maximum end-of-the-month net effect of the Rochers Weir is in September when it introduces a reduction of 0.13 foot in the level regulated by the Bennett Dam.

Figure 1 shows the changes in the lake levels during the navigation season due to the operation of the Bennett Dam only for the 12-yr period. The maximum reductions vary from about 0.1 to 0.9 foot with a mean value of about 0.5 foot, and occur in July or August.

Figure 2 shows the changes in the levels due to the operation of the Bennett Dam and the Rochers Weir. The maximum reductions in this case vary from about 0.2 to 1.2 feet with a mean value of about 0.6 foot, and occur in July or August.

Table 3:- 12-yr Mean Values of the Various Variables for Great Slave Lake at Yellowknife Bay, ft

Variable	J	F	M	A	M	J	J	A	S	O	N	D	Peak
N	513.88	513.89	513.87	513.78	514.26	514.79	515.05	514.88	514.55	514.12	513.84	513.84	515.10
BD	514.07	514.17	514.23	514.17	514.46	514.58	514.61	514.44	514.22	513.90	513.81	513.98	514.71
BD+RW	514.13	514.24	514.30	514.26	514.49	514.58	514.58	514.35	514.09	513.78	513.75	514.01	514.72
BD-N	0.19	0.28	0.36	0.39	0.20	-0.21	-0.44	-0.44	-0.33	-0.22	-0.03	0.14	-0.39
BD+RW-N	0.25	0.35	0.43	0.48	0.23	-0.21	-0.47	-0.53	-0.46	-0.34	-0.09	0.17	-0.38
BD+RW-BD	0.06	0.07	0.07	0.09	0.03	0	-0.03	-0.09	-0.13	-0.12	-0.06	0.03	0.01

GSC Datum (1968). Add 0.32 foot to compute levels dorresponding to previous datum.

N = Natural Lake Levels

BD = Regulation by the Bennett Dam only

BD+RW = Regulation by the Bennett Dam and the Rochers Weir

BD-N = Change in Lake Level due to the Regulation by the Bennett dam only

BD+RW-N = Change in Lake Level due to the Regulation by the Bennett Dam and the Rochers Weir

BD+RW-BD = Net Effect of the Rochers Weir

FIG. 1 – Change in Levels of Great Slave Lake Due to Regulation by the Bennett Dam only (May 31 to October 31)

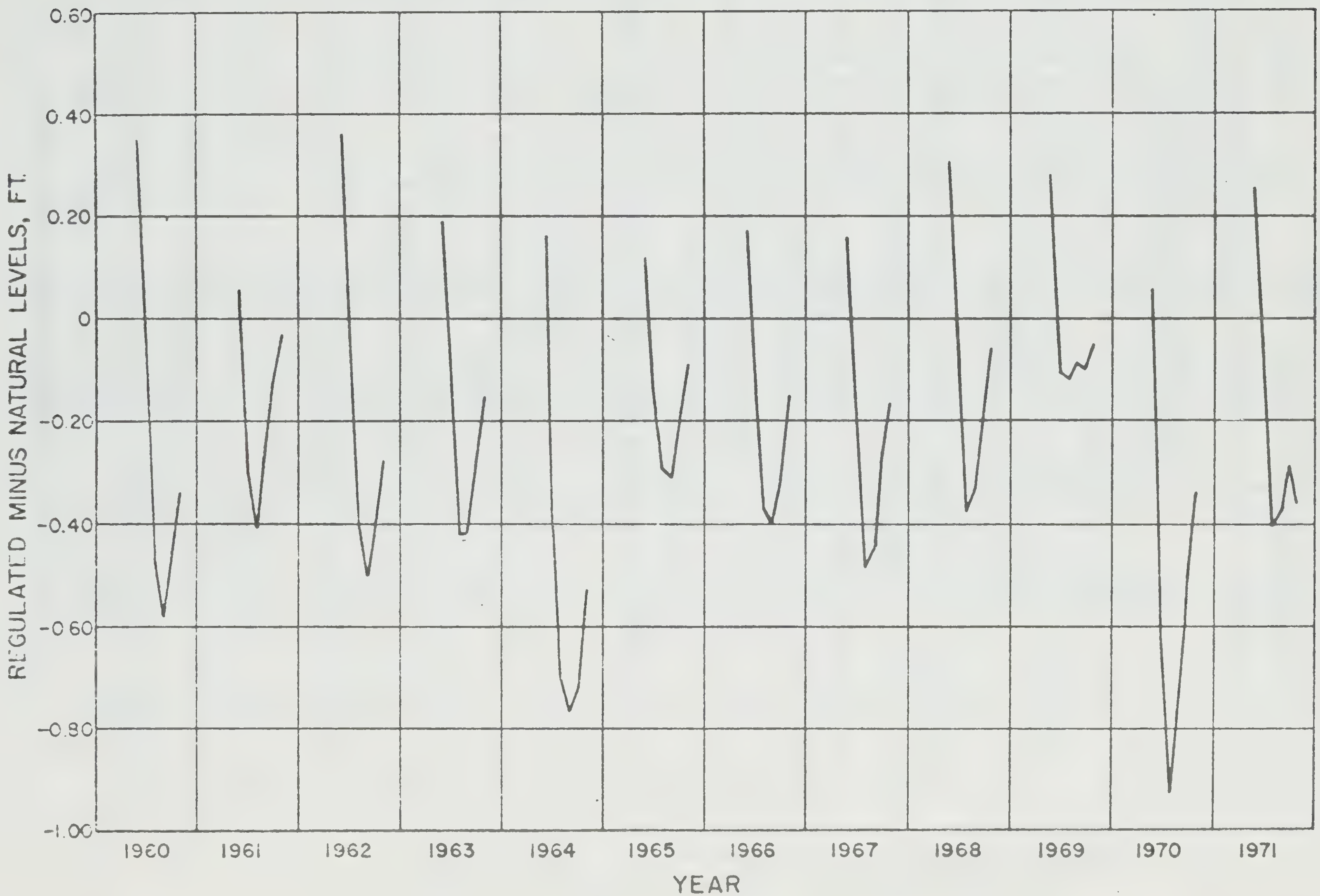

FIG. 2:—Change in Levels of Great Slave Lake Due to Regulation By the Bennett Dam and the Rochers Weir (May 31 to October 31)

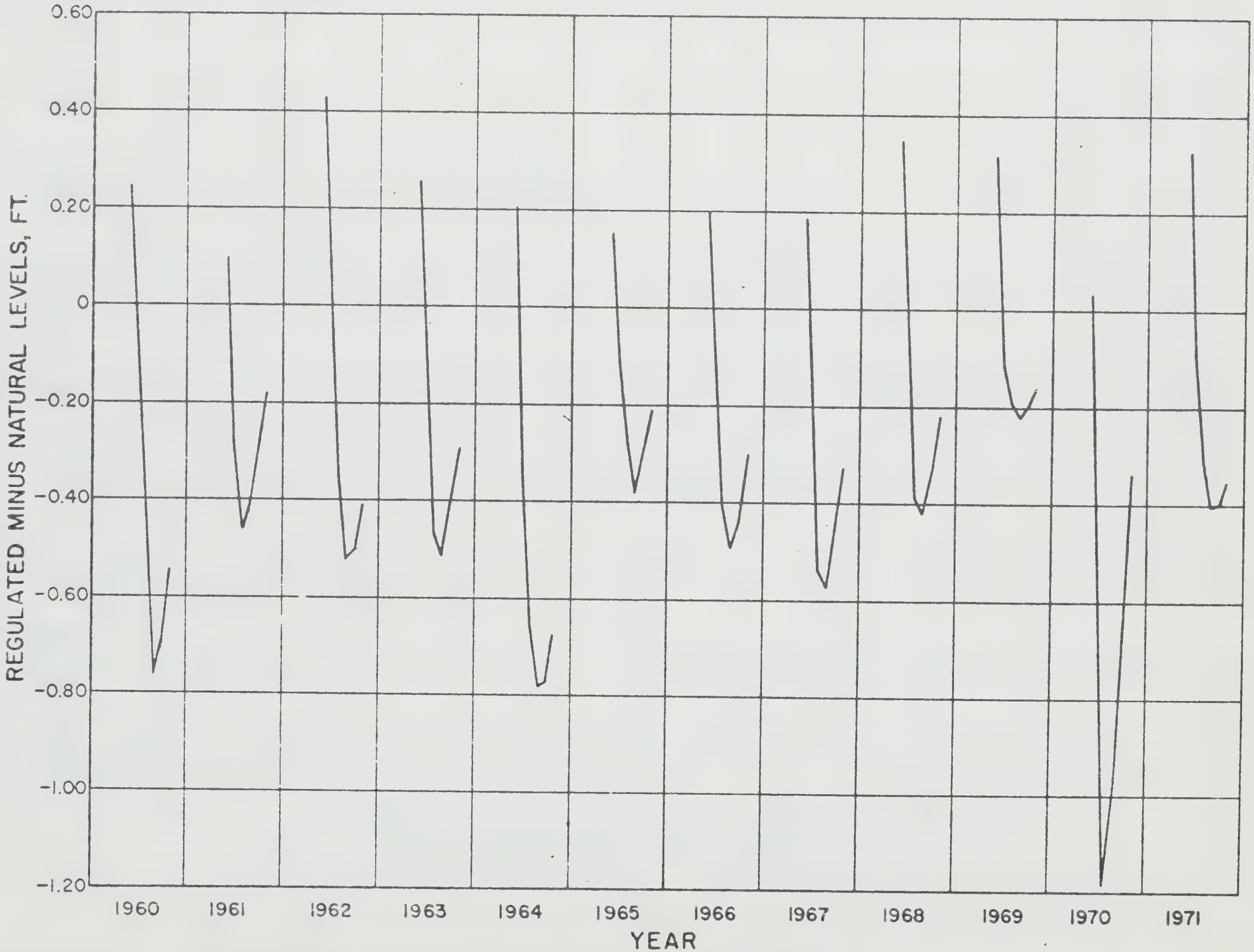

Figure 3 shows the net effect of the Rochers Weir. The maximum reductions vary from about 0.1 to 0.25 foot with a mean value of about 0.15 foot and generally occur in September or October.

EFFECTS ON THE MACKENZIE RIVER

The relationships between the levels of Great Slave Lake at Yellowknife Bay and the flows of the Mackenzie River near Fort Providence for open water as well as for ice conditions have been derived in the Athabasca-Mackenzie Basin Report (1971). Using the open-water relationship, the changes in the flows of the Mackenzie River were computed from the changes in lake levels give in table 2. These changes at different probabilities are given in table 4. The mean monthly natural flows of the Mackenzie River near Fort Providence from May to November are 150, 242, 271, 266, 249, 230, and 172 thousand cfs respectively. Thus, the changes due to regulation are small and hardly exceed 10% of the natural flows during the navigation season.

CONCLUSION

The following conclusions can be drawn from this study:

1. The Bennett Dam has caused and will continue to cause changes in the regime of the Slave River, Great Slave Lake and the Mackenzie River although these changes are small compared to those caused in the regime of the Peace River alone.
2. The Rochers Weir will retard the outflow from Lake Athabasca. This will cause a reduction in the flows of the Slave and the Mackenzie Rivers and levels of Great Slave Lake in the latter part of the navigation season. During the winter and spring months, these flows and levels will be higher with the Rochers Weir than with the Bennett Dam alone, although the effect will be small.

FIG. 3:– Net Effect of the Rochers Weir on the Levels of Great Slave Lake (May 31 to October 31)

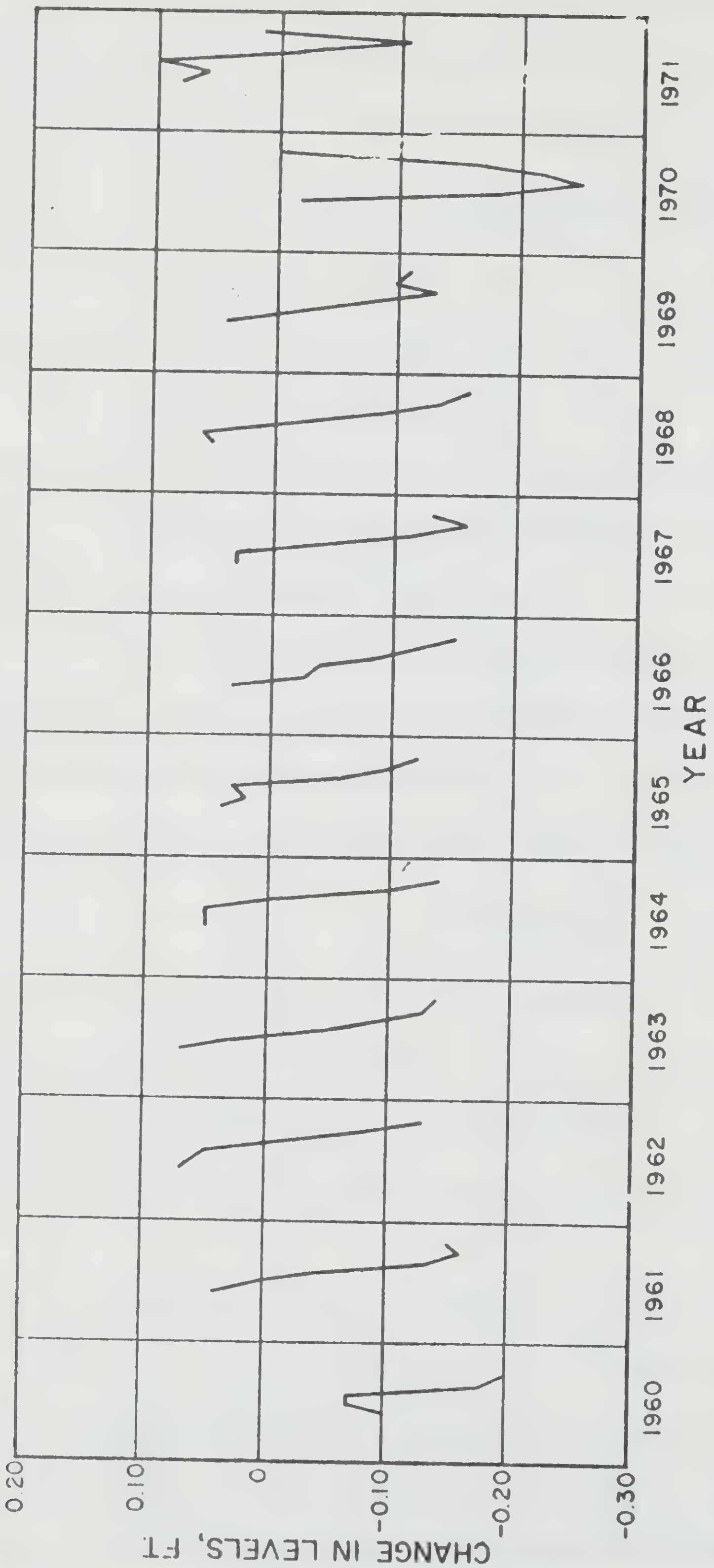

Table 4:- Changes in flows of the Mackenzie River Near Fort Providence, cfs

	May 31			Peaks			October 31		
P	BD-N	BD+RW-N	BD+RW-BD	BD-N	BD+RW-N	BD+RW-BD	BD-N	BD+RW-N	BD+RW-BD
.05	12900	12900	0	-41800	-36700	5100	-25700	-38600	-12900
.10	12900	13400	500	-41800	-35400	6400	-21200	-34100	-12900
.25	14800	18000	3200	-28900	-25800	3100	-16100	-22500	-6400
.50	11600	14800	3200	-28900	-27700	1200	-12900	-19300	-6400
.75	12900	14800	1900	-16100	-14800	1300	-7700	-12900	-5200
.90	13500	17400	3900	-27000	-27000	0	-9300	-12900	-3600
.95	14800	19300	4500	-32200	-32200	0	-6700	-10300	-3600

P = Probability of exceedance

N = Natural flows

BD = Regulation by the Bennett Dam only

BD+RW = Regulation by the Bennett Dam and the Rochers Weir

BD-N = Change in flows due to the Regulation by the Bennett Dam only

BD+RW-N = Change in flows due to the Regulation by the Bennett Dam and the Rochers Weir

BD+RW-BD = Net Effect of the Rochers Weir

3. The mean maximum reduction in the levels of Great Slave Lake due to the regulation by the Bennett Dam without the Rochers Weir will be about 0.5 foot (Fig. 1) and with the Rochers Weir it will be about 0.6 foot (Fig. 2). The maximum reductions due to these regulations occur in July or August.

4. The mean maximum reduction in the levels of Great Slave Lake due to the effect of the Rochers Weir will be about 0.15 foot. This effect is generally maximum in September or October (Fig. 3).

REFERENCES

1. Coulson, A. and Adamcyk, R.J., "The Effects of the W. A. C. Bennett Dam On Downstream Levels and Flows", Technical Bulletin No. 18, Inland Waters Branch, Department of Energy, Mines and Resources, 1969.

2. "Estimated Changes in the Hydrologic Regime of the Mackenzie Basin as a Result of Diversions into the Saskatchewan-Nelson System: Apendix A of the Effects of Southward Diversion on the Athabasca-Mackenzie Basin", Report prepared by the Engineering Division, Water Planning and Operation Branch, September 1971.

SECTION I

DEPARTMENT OF THE ENVIRONMENT
WATER SURVEY OF CANADA

SECTION I

1971
SEDIMENT SURVEY
FOR THE
PEACE-ATHABASCA DELTA REGION

Prepared by: D. R. Graham

Approved by: R. D. May,
District Ehgineer

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INTRODUCTION

The sediment program for the Peace-Athabasca Delta Project consisted of sampling at seventeen different river locations and on five lakes. At nearly all locations both suspended sediment and bed material samples were obtained. All samples were shipped to Water Survey of Canada laboratory located in Regina.

At most locations velocities encountered were low enough and the depth shallow enough to allow use of lightweight hand samplers (DH48 and DH59). For the same reasons, a bucket-type (Lane) sampler was used for bed material sampling. On larger rivers, such as the Athabasca and its distributary channels, larger samplers had to be used. For suspended sediment a D-49 and for bed material a BMH-60 was used. On the Riviere des Rochers and the Peace River, a P-61 suspended sediment sampler was used along with a BMH-60 bed sampler. Suspended sediment samples were obtained with each measurement. At various times, complete depth integrated sediment measurements were taken on the major streams. Suspended sediment samples in the lakes were obtained using an instantaneous trap sampler. For the bed material a Lane sampler was used on all lakes except Lake Athabasca where a BMH-60 bed material sampler was used.

SOURCES OF DATA

The data compiled herein is a co-ordinated effort of Water Survey of Canada (Environment Canada) and the Alberta Water Resources Division (Department of the Environment). Data was collected for most stations from the Peace-Athabasca Delta Project Camp, located in Fort Chipewyan. Results for the Athabasca River and its distributary channels were collected by Water Survey of Canada's Fort McMurray sub-office. The Peace River at Peace Point and the Slave River at Fort Smith sites were sampled by staff of the Water Survey of Canada Fort Smith sub-office.

For further information and results, please feel free to contact:

Water Survey of Canada,
Department of the Environment,
110 - 12th Avenue S. W.,
Calgary, Alberta.

LIST OF SEDIMENT SAMPLING LOCATIONS

NAME	NUMBER
Athabasca River at Embarras Airport	15
Athabasca River below McMurray	12
Baril Lake Sediment Locations	BL-12
Big Point Channel below Divergence	26
Birch River below Alice Creek	9
Chenal des Quatre Fourches below Four Forks	4
Embarras River below Divergence	23
Fletcher Channel below Divergence	24
Goose Island Channel below Divergence	25
Harrison River near the Mouth	20
Lake Athabasca Sediment Locations	LA-1—LA-8A
Lake Claire Sediment Locations	LC-7—LC-9
Lake Mamawi Sediment Locations	ML-6,ML-10,ML-11
Mamawi Lake Channel at Dog Camp	39
McIvor River near the Mouth	22
Old Fort River near the Mouth	21
Peace River at Peace Point	8
Prairie River near Lake Claire	46
Revillon Coupé below confluence Riviere des Rochers . . .	44
Richardson Lake Sediment Locations	RL-13,RL-14
Riviere des Rochers at Ben Houles' Cabin	28
Slave River at Fort Smith	13

RESULTS

Preliminary examination of suspended sediment results indicates very little correlation with flow (see Figures 1-5). In all but one plotting (Figure 1) of measured discharge versus measured suspended sediment concentration, the results appear almost as a random plot. Figure 1, for the Athabasca River at Embarras Airport approaches what would be expected in most streams. Without mean daily flows for all stations, a more complete analysis is not possible.

The only obvious aspect of the available sediment analysis results is the very low sand (>.50 mm) concentrations in streams leaving Lake Athabasca. Again, Athabasca River at Embarras Airport and other streams entering the lake approach what might be thought of as normal for sand concentrations (20-30%).

Figure - 1

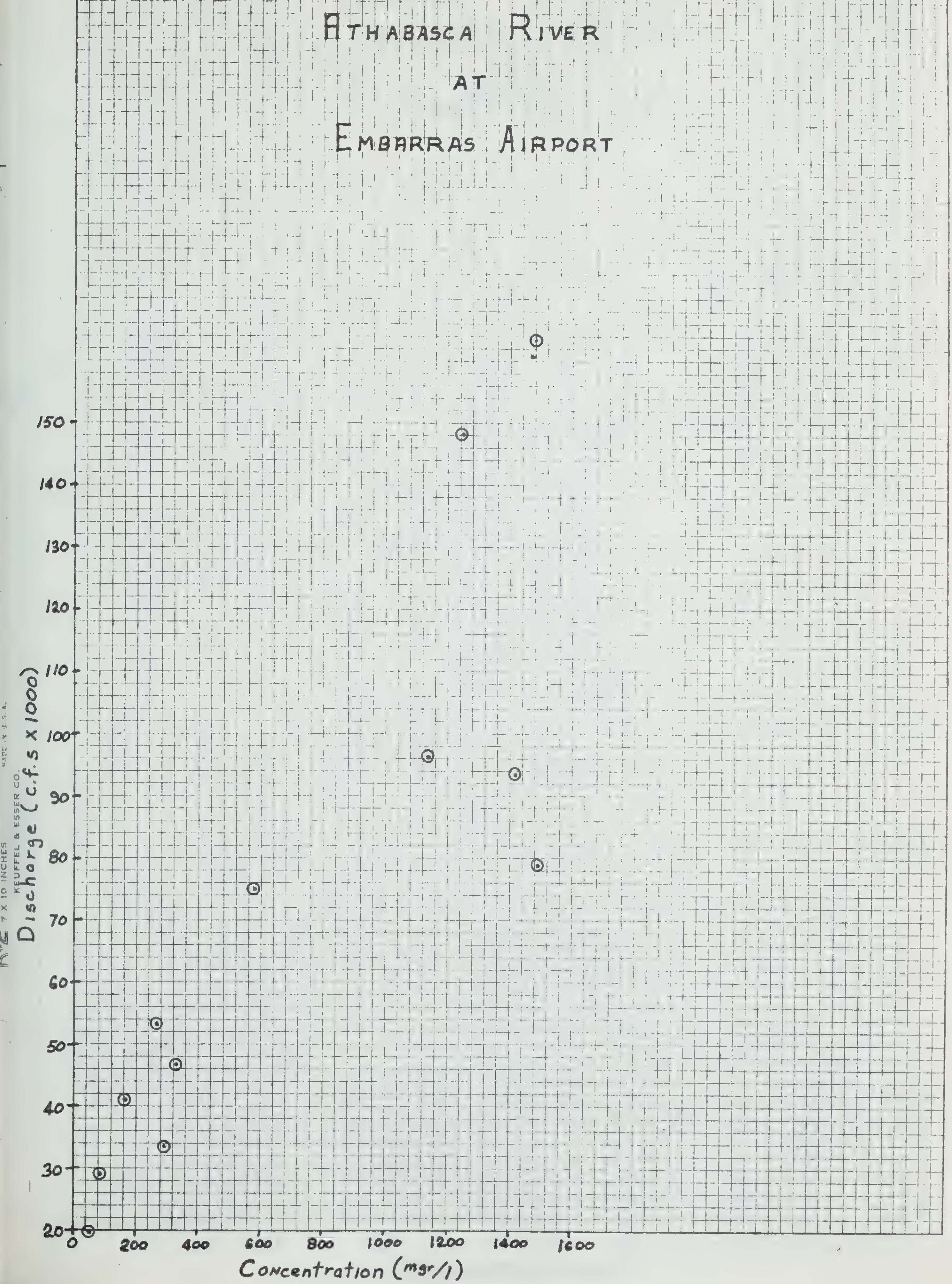

ATHABASCA RIVER
AT
EMBARRAS AIRPORT
Discharge (c.f.s x 1000)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
200
400
600
800
1000
1200
1400
1600
Concentration (mgr/l)

Figure - 2

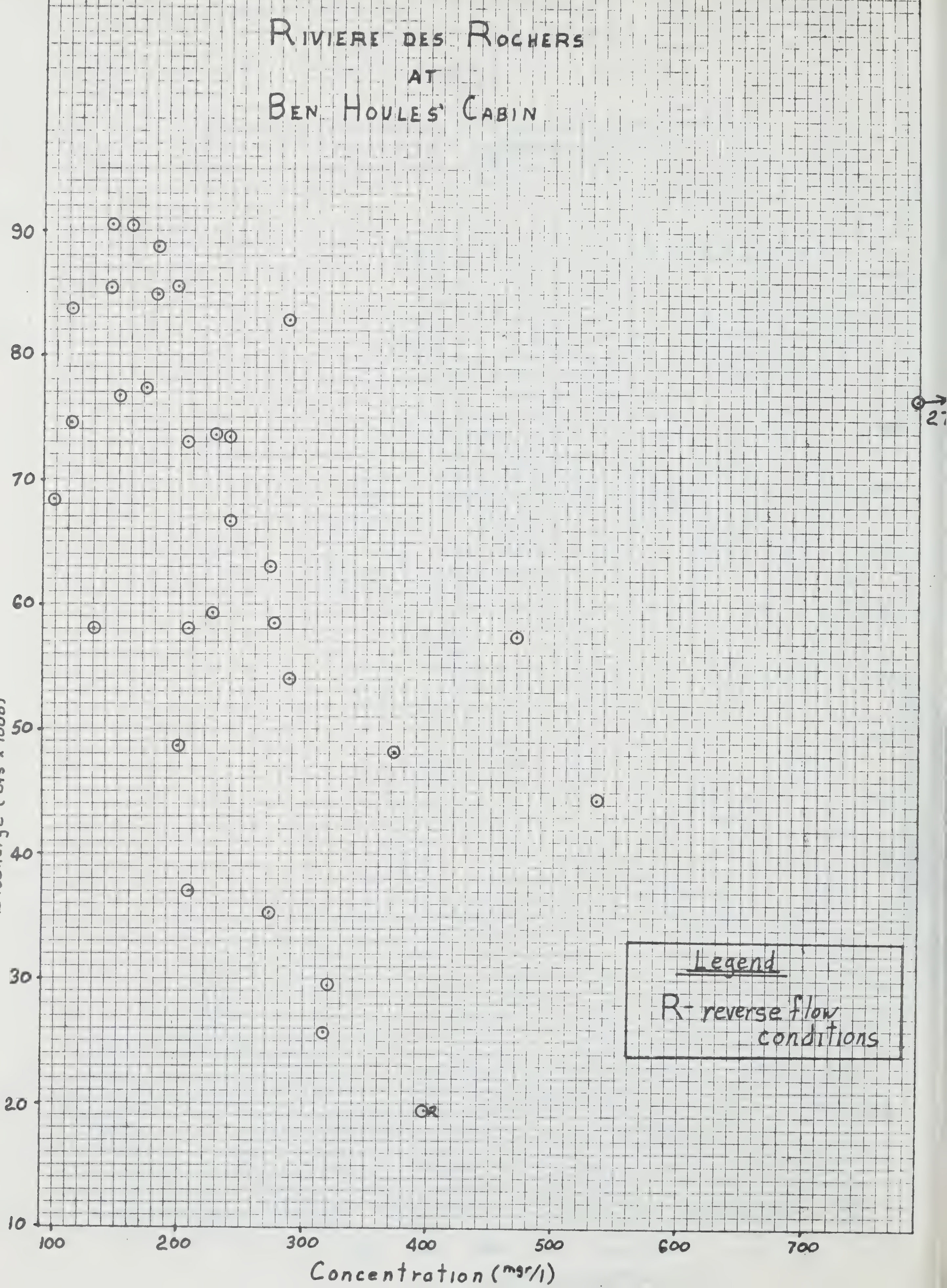
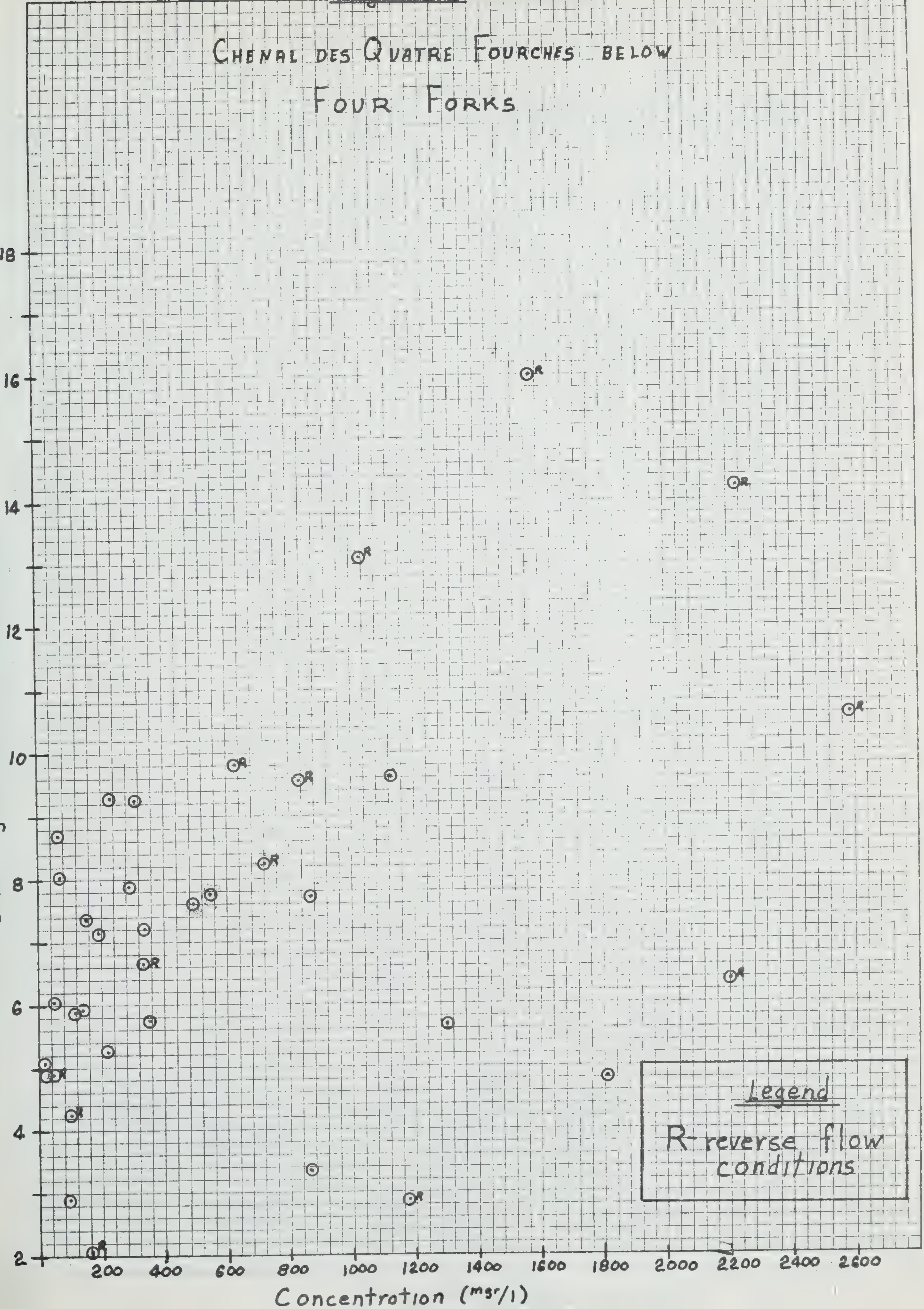

RIVIERE DES ROCHERS
AT
BEN HOULES' CABIN
Discharge (cfs x 1000)
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
Concentration (mgr/l)
R
27
Legend
R- reverse flow conditions

Figure - 3


CHENAL DES QUATRE FOURCHES BELOW
FOUR FORKS
Discharge (cfs x1000)
Concentration (mgr/1)
2
4
6
8
10
12
14
16
18
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
R
Legend
R-reverse flow conditions
KEUFFEL & ESSER CO.

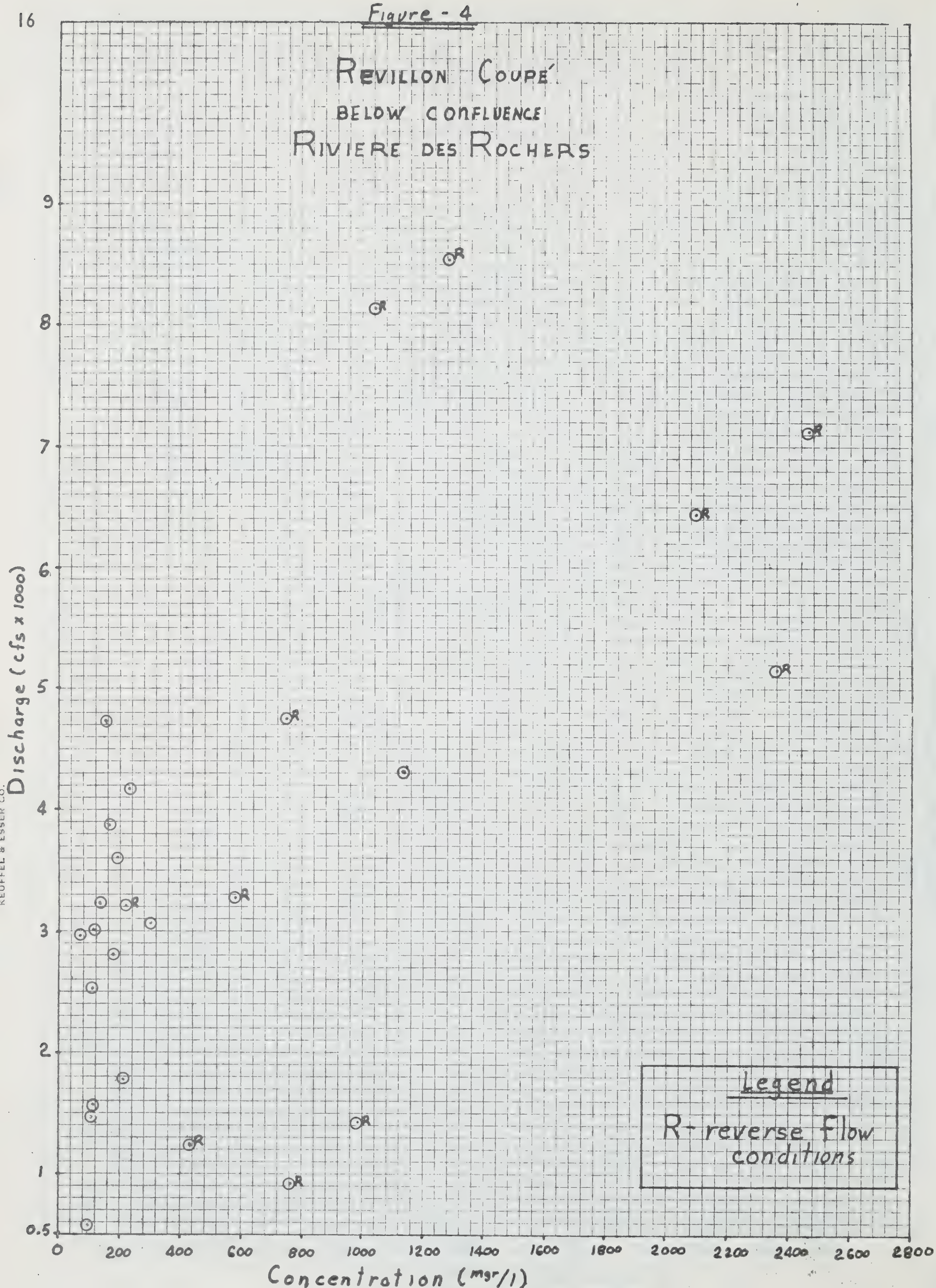
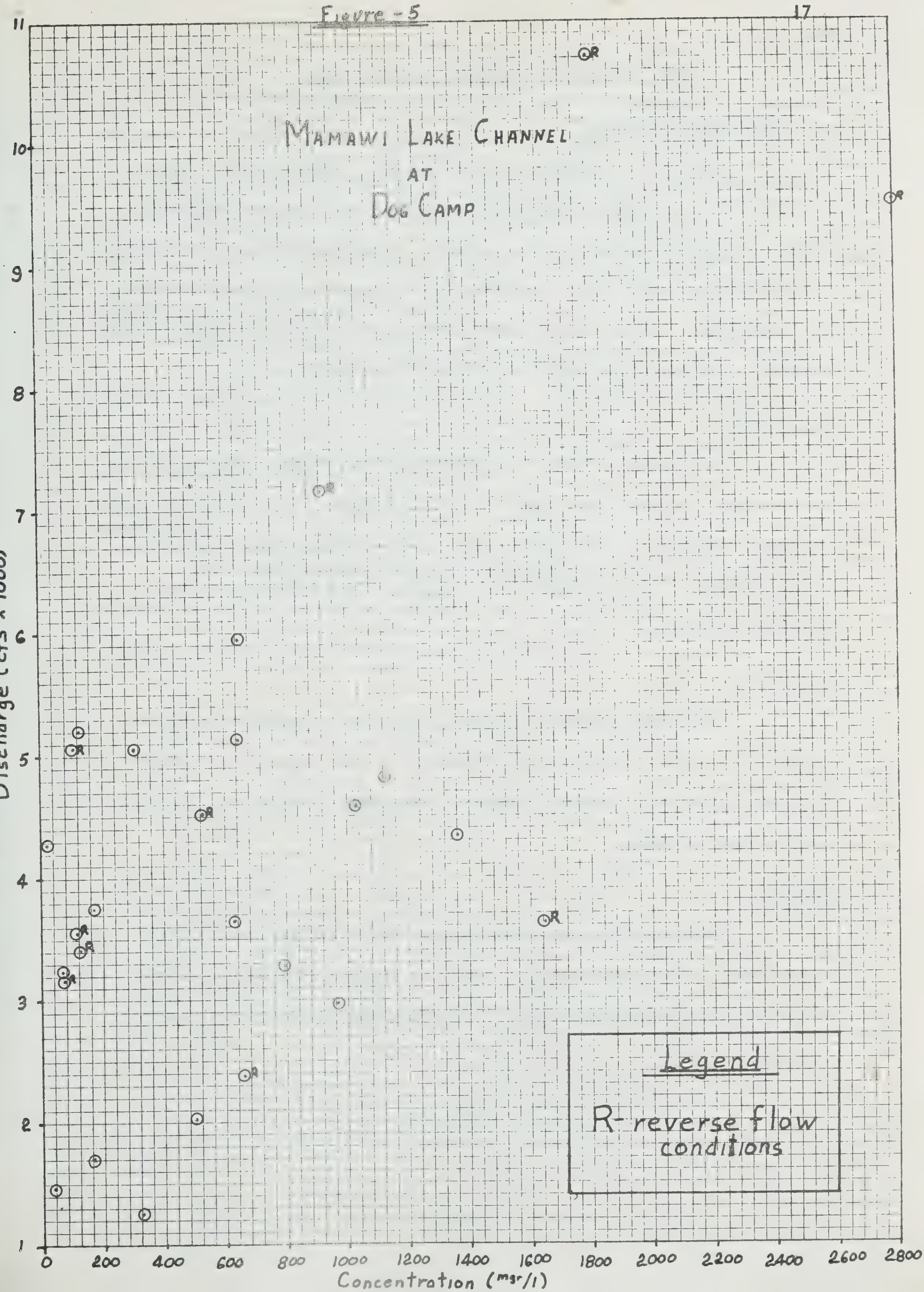


Figure - 4
REVILLON COUPÉ
BELOW CONFLUENCE
RIVIERE DES ROCHERS
Discharge (cfs x 1000)
Concentration (mgr/l)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
0.5
1
2
3
4
5
6
7
8
9
16
Legend
R - reverse flow conditions
R

Figure - 5



MAMAWI LAKE CHANNEL
AT
DOG CAMP
Discharge (cfs x 1000)
Concentration (mgr/l)
Legend
R- reverse flow conditions
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
2
3
4
5
6
7
8
9
10
11
R

DESCRIPTIONS OF SEDIMENT SAMPLERS USED

U.S. DH-48 and U.S. DH-59:

These two samplers, as illustrated in Figure 6 and 7, are very similar in nature. The DH-48 sampler weighs four and one-half pounds and the DH-59 twenty-four pounds. These samplers are used for shallow streams which can be waded or for streams of medium depth and low velocities. Each sampler comes equipped with three different sized nozzles: 1/4 inch, 3/16 inch and 1/8 inch diameter.

U.S. D-49:

For larger streams which are less than eighteen feet deep the D-49 sampler is used (see Figure 8). This sampler is twenty-four inches long and weighs sixty-two pounds, and comes with the three different sized nozzles. It is designed for sampling using a cable and reel suspension system.

U.S. P-61:

For greater depths or rivers with high velocities, a 100-pound P-61 sampler is necessary (Figure 9). This sampler is equipped with an electrically operated valve so that point samples or integrated samples may be taken.

BMH-60:

The BMH-60 bed material sampler weighs thirty pounds (see Figure 10), and is restricted to lakes or streams of moderate depths and velocities where bed material is soft and does not contain much gravel.

"The sampler mechanism of the U.S. BMH-60 consists of a scoop or bucket driver by a cross curved constant torque motor-type spring that rotates the bucket from front to back. The scopp, when activated by release of tension on the hanger rod, can penetrate into the bed about 1.7 inches and can hold approximately 175 cc of material".

Instantaneous Trap Sampler:

This sampler is designed to be used on lakes or places where a sample at a particular point is required. The sampler consists of a long cylinder which has a spring trap door at either end and can be closed mechanically at any desired depth.

Lane Sampler:

This light weight bed material sampler is very easy and quick to use. It is a bucket-type sampler which is dragged along the bottom of the stream to scoop up a sample.

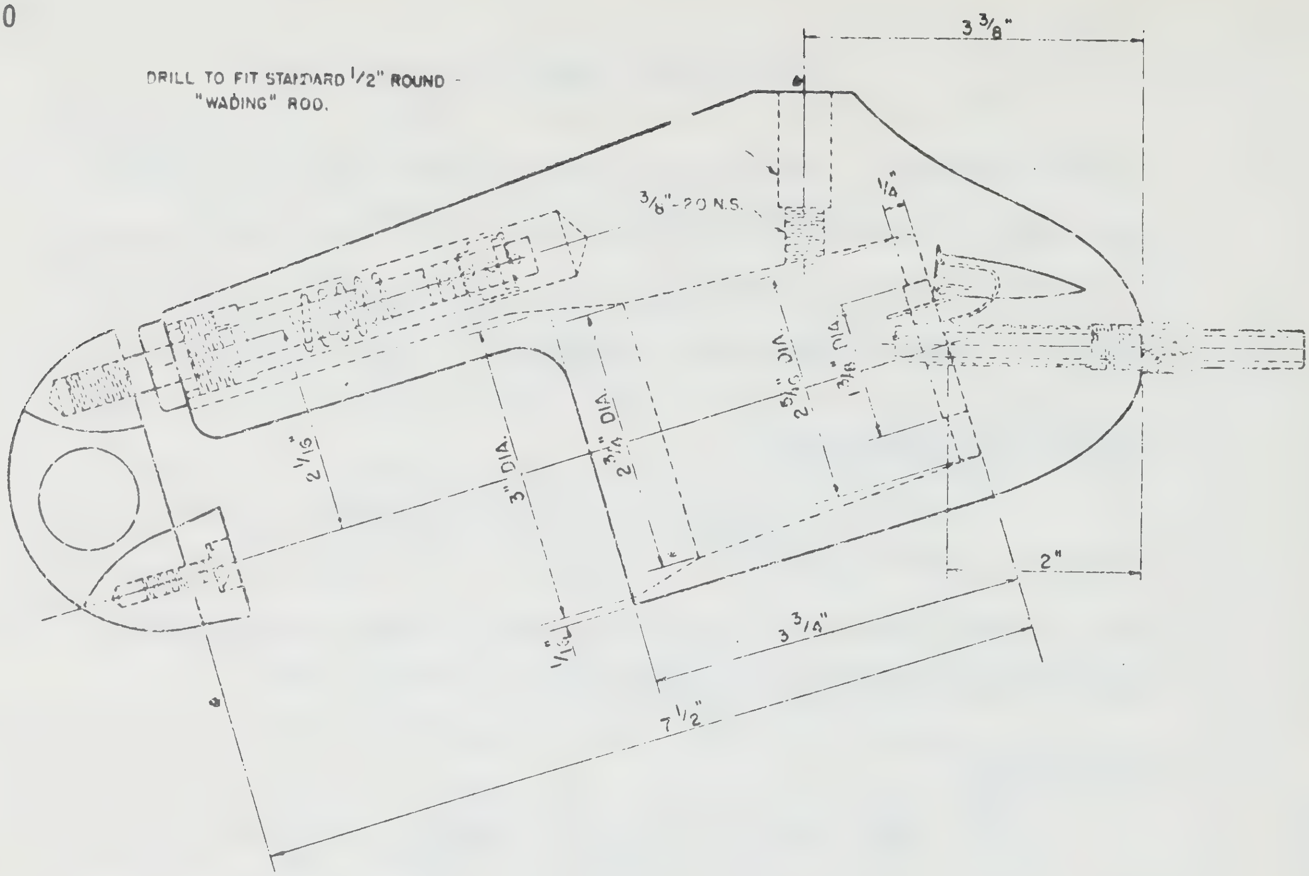


Fig. 6 DEPTH-INTEGRATING WADING TYPE HAND SAMPLER, US DH-48

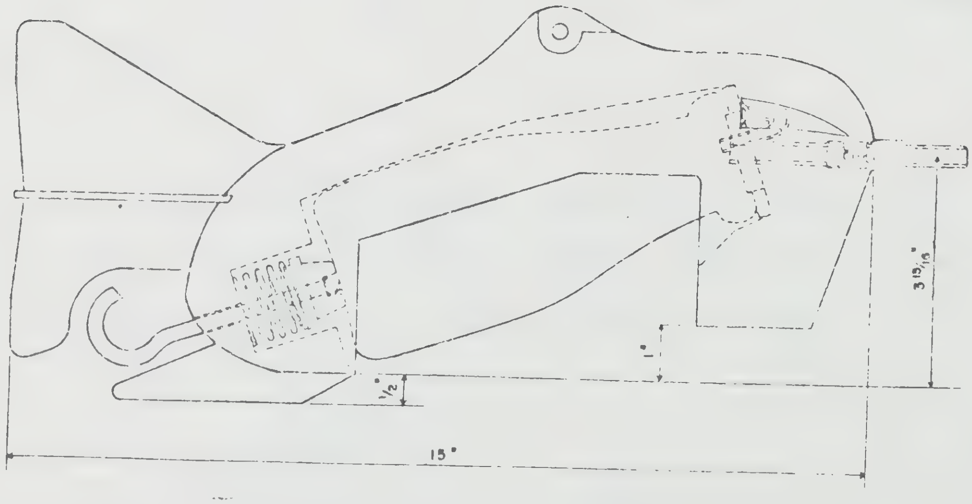


Fig. 7 DEPTH-INTEGRATING HAND LINE SAMPLER, US DH-59

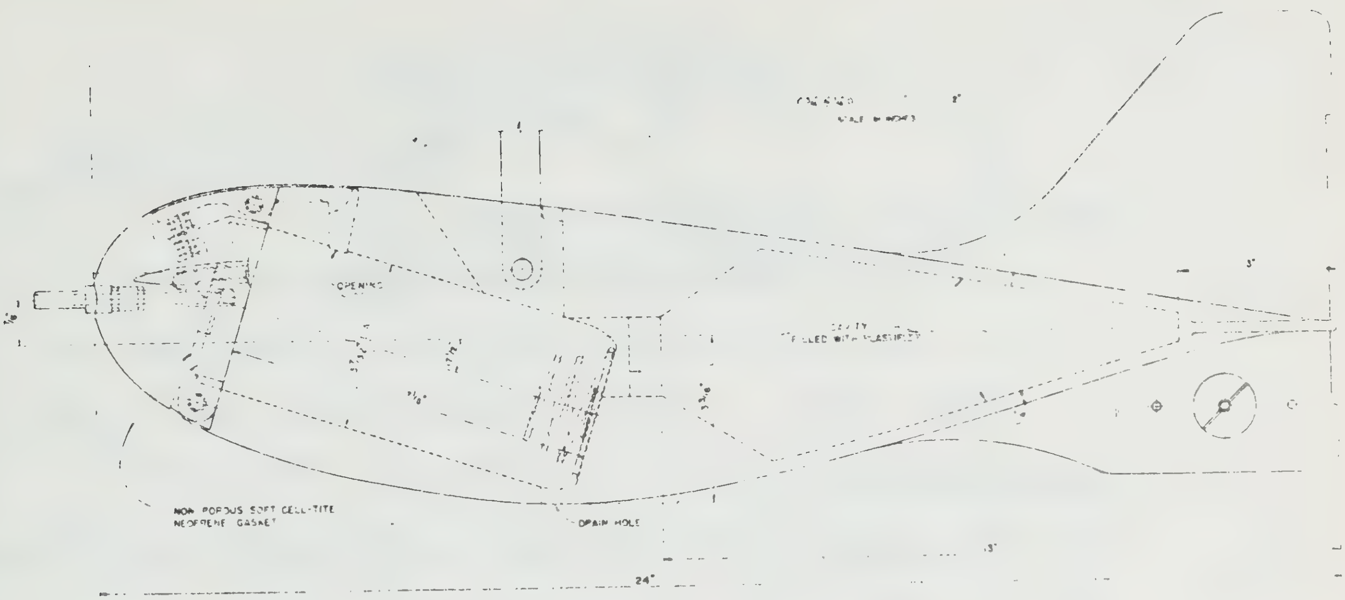


Fig. 8 DEPTH-INTEGRATING SAMPLER, US D-49

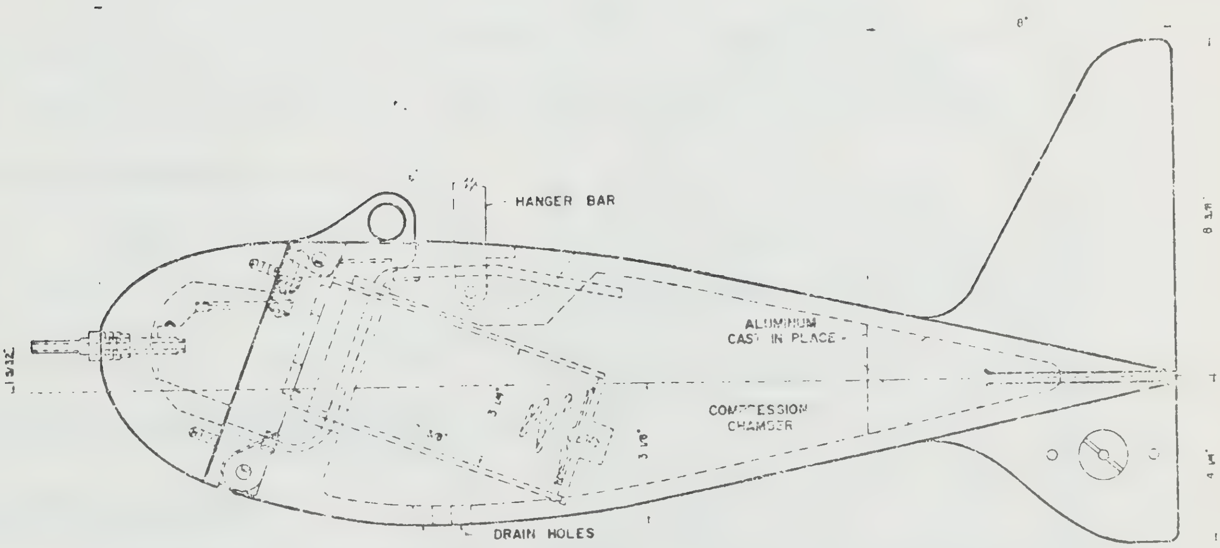


Fig. 9 POINT-INTEGRATING SAMPLER, US P-61

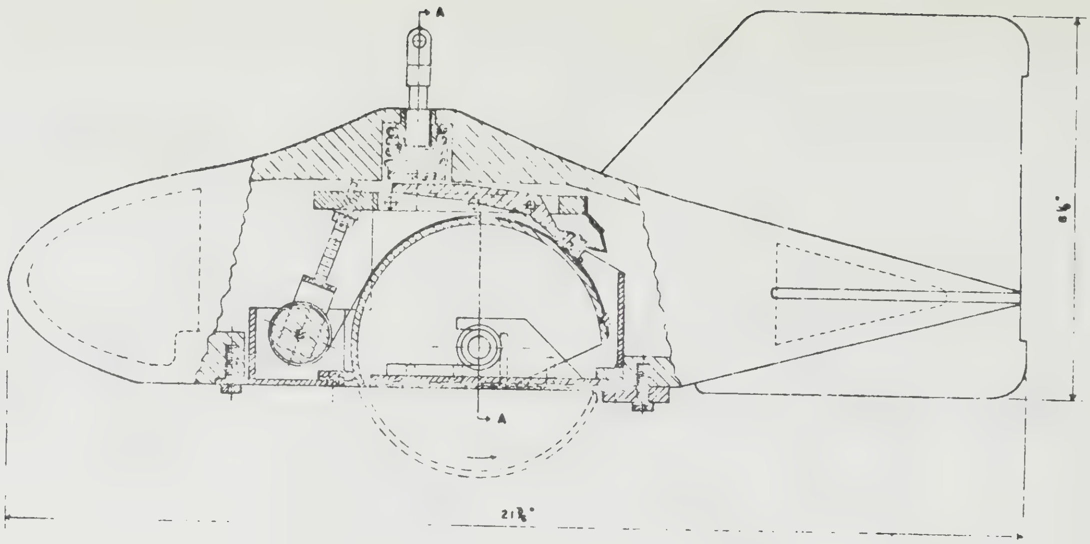


Fig. 10 HAND-LINE BED-MATERIAL SAMPLER, US BMH-6(

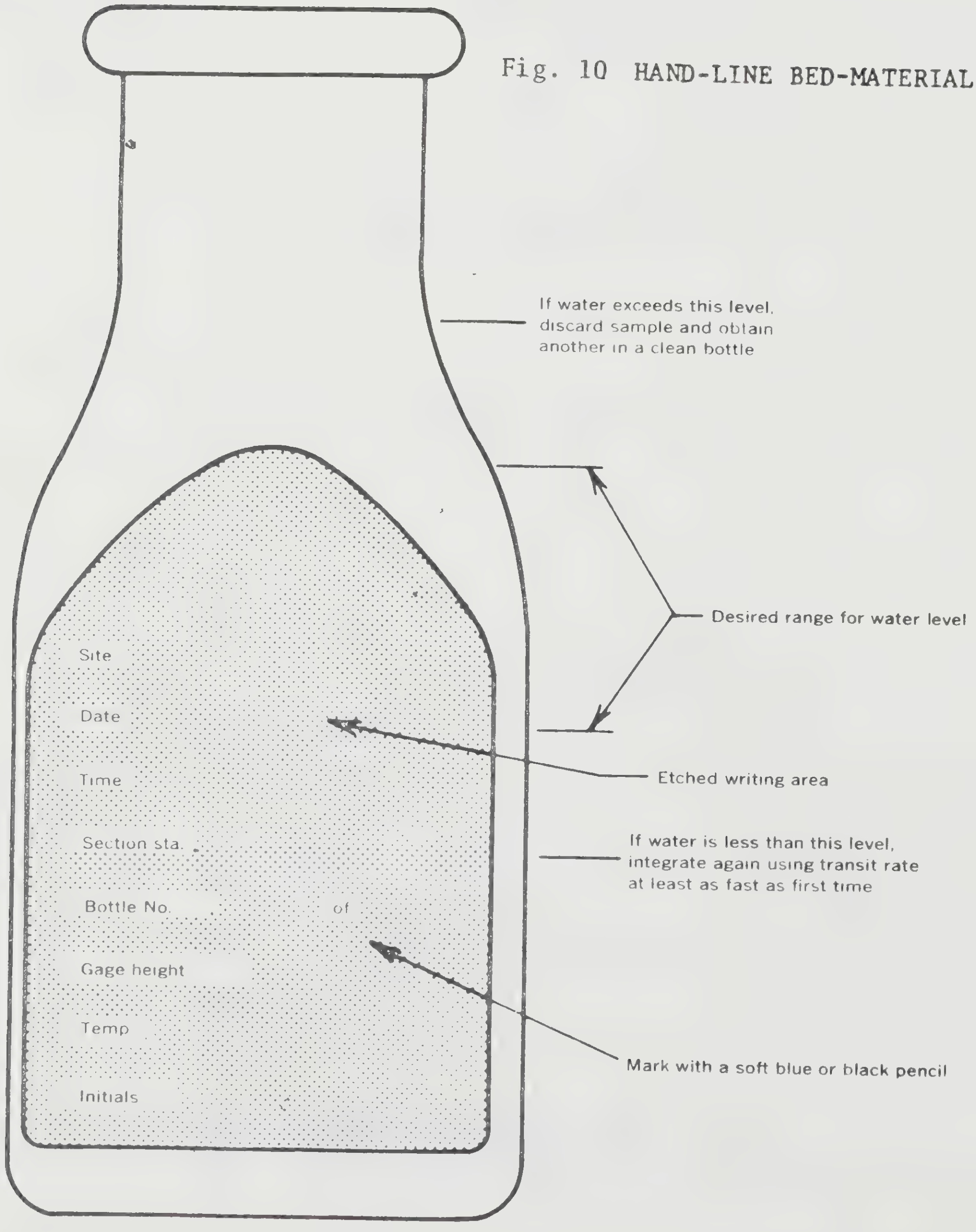


Fig. 11 Diagram of sample bottle showing desired water levels and essential recorded information. Sometimes other information concerning type of sampler used, the section location, and stream conditions should also be noted.

SEDIMENT SAMPLING TECHNIQUES

Suspended Sediment Sampling:

All suspended sediment samplers are used in the same manner. The sampler type and size depends on the river velocity and depth. The sampler should be lowered and raised at uniform rates which will give a sample size as indicated in Figure 11. If the sampler is raised or lowered too fast, the sampler will not stay in a horizontal position. Nozzle size adjustment is used to ensure proper sampling conditions.

If the river is too fast or deep to get within the above limits, then a point intergrated sampler must be used. This allows for the sampling of only a portion of the depth at one time. The controllable electric valve ensure this.

The instantaneous trap sampler is used when samples at a known depth is required. The ends are opened and the sampler lowered into the water to the desired depth. A messenger weight is dropped to activate the spring and close the ends. Samples are taken from near the bottom, middle and surface.

Depth integrated sediment measurements samples were taken at the station in which 10, 30, 50, 70 and 90 per cent of the total flow had been measured. Most sediment samples were obtained at approximately the 50 per cent flow vertical.

Bed Material Sampling:

The "BMH-60" bed material sampler and the "Lane Sampler" were used for this project. Samples were obtained from the same verticals as suspended sediment as well as at the water's edge, high water mark

and half way to high water mark on each bank. One sample is obtained from each vertical. These were obtained twice, once in the spring and once in the fall.

SEDIMENT STATION ANALYSIS

Athabasca River at Embarras Airport:

Samples were taken at ten different times during the season with five complete sediment measurements being done. Bed material was sampled twice. Work was done using a boat.

Athabasca River below McMurray:

This is a major continuing sediment station with a complete suspended and bed material program.

Baril Lake Sediment Location:

Samples were obtained on July 20 and October 23, using a helicopter for transportation. The lake was shallow enough that suspended sediment and bed samples were dipped by hand.

Big Point Channel below Divergence:

Samples were obtained on ten different dates using a D-49 or DH-59 suspended sediment sampler. Two complete sediment measurements were made.

Birch River below Alice Creek:

A "DH-59" sampler and a "Lane" sampler were used to obtain the samples. All work was done by boat.

Chenal des Quatre Fourches below Four Forks:

Forty suspended sediment samples were obtained. Four complete sediment measurements were included. Bed material was obtained on two different dates. All work was done from a boat.

Embarras River below Divergence:

Samples were obtained on nine different dates with complete sediment measurements.

Fletcher Channel below Divergence:

Samples were obtained on ten different dates. Two complete sediment measurements were obtained.

Goose Island Channel below Divergence:

Samples were obtained on ten different dates with two complete sediment measurements.

Harrison River near the Mouth:

Only one sample was obtained from this station.

Lake Athabasca Sediment Locations:

Samples were obtained three times during the summer. On June 30, a fixed-winged aircraft was used and because of the roughness of the lake had to land in sheltered areas that were not good sampling locations. Samples taken in July and October were taken at different locations. Samples were taken in a line extending from the Mouth of Big Point Channel towards Bustard Island.

Lake Claire Sediment Locations:

A fixed-winged aircraft was used as transportation. Only two locations were sampled in June. A third location was added for samples taken in July and October.

Lake Mamawi Sediment Locations:

A fixed-winged aircraft was used in June and a helicopter in July and October.

Mamawi Lake Channel at Dog Camp:

Samples were obtained from a boat. Thirty-two samples were obtained at different dates, with two of these being complete sediment measurements. Bed samples were obtained twice during the season.

McIvor River near the Mouth:

Only one sample was obtained here.

Old Fort River near the Mouth:

Only one sample was obtained here.

Peace River at Peace Point:

This is a continuing sediment sampling station with a very limited program. A few bed material and complete sediment measurements have been taken.

Prairie River near Lake Claire:

Sampling on the Prairie River started the end of July. Samples were obtained on nine different dates with two complete sediment measurements. Bed material was obtained twice during the season.

Revillon Coupé below confluence Riviere des Rochers:

Samples were obtained by boat. Samples were obtained on thirty-four different dates with only one complete sediment measurement. Bed material was not sampled at this location.

Richardson Lake Sediment Locations:

Richardson Lake was sampled in August and then again in October. A fixed-winged aircraft was used as transportation. Sample locations in August were described as RN and RS, but were changed to No. 14 and No. 13, respectively.

Riviere des Rochers at Ben Houles' Cabin:

Sampling was done using a boat. Because the depths were around 40 to 50 feet, sample "A" was taken from the bottom to mid-depth and sample "B" from mid-depth to top. Samples were obtained on 51 different dates with four of these being complete sediment measurements. Bed material was obtained twice during the year.

Slave River at Fort Smith:

Daily sediment sampling started in August and continued on until October 21, with a weeks record being missed at the end of August. Samples were obtained at the Fort Smith water pumping station. A pumping system was developed from which daily samples could be obtained.

A P P E N D I X

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH_WATER SURVEY OF CANADA

R 387
(9-67)

Suspended Sediment Analysis Results

Stream ATHABASCA RIVER AT EMBARRAS for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					AE																		
11	0955	BYR	9.96	D49	1AB	M	17.8	21.8		1100	11.9	11.6	11.8	527	.1285	244							
"		JCD		"	2AB	"	21.0	19.8		845	10.9	10.6		616	.2584	419							147
"	1050	"		D49	3AB	"	17.4	19.8		600	10.9	10.6		585	.2138	365							156
"	1130	JCD			4AB	"	20.0	20.2		300	14.1	13.8		698	.2278	326							158
11		JCD			5AB	M	21.0	21.0		150	15.4	15.1		735	.2192	298							159
JUNE					AE																		156
4	1030	JCD		D49	6AB	M	21.2	24.0		#5	10.5	10.2	21.0	540	.0593	110							
"	1120	"		"	7AB	"	20.0	20.6		#10			"	587	.1267	216							187
"	1205	"		"	8AB	"	20.8	22.2		#15	8.0	7.7	"	567	.1037	183							185
"	1405	"		"	9AB	"	18.2	20.8		#21	11.8	11.5	"	682	.0917	134							195
4	1445	JCD		D49	10AB	M	21.2	19.8		#24	12.0	11.7	21.0	740	*.5514	745							192
			AE 11 and AE 12 Bed material																				190
14	1540	JD		D49	13AB	M	13.2	14.0		#15	15.9	15.6	18.3	521	.7758	1489	.0180	.1784	342	23.0	57.0	20.0	
15	0945	"		"	14AB	S	20.2	21.0		#5	19.2	16.9	16.5	468	.5720	1222	.0102	.0458	98	8.0	60.0	32.0	165
"	1030	"		"	15AB	S	21.6	25.0		#10	15.1	14.8	16.3	483	.7477	1548	.0137	.1645	341	22.0	50.0	28.0	181
"	1130	"		"	16AB	S	26.8	30.0		#15	15.8	15.5	16.3	525	.8380	1596	.0146	.1927	367	23.0	50.0	27.0	162
"	1225	"		"	17AB	S	26.8	28.0		#21	21.0	20.7		591	.8277	1401	.0114	.0993	168	12.0	58.0	30.0	166
15	1345	JD		D49	18AB	S	29.0	28.8		#24	21.6	21.3		626	.8478	1354	.0103	.0933	149	11.0	57.0	32.0	159
			AE 19 to AE 23 Bed material																				157
JULY					AE																		
6	0945	BB		D49	24AB	S	33.6	34.0		#5	17.5	17.2	17.0	546	.2372	434							
"	1040	"		"	25AB	S	34.2	32.2		#10	16.3	16.0	16.8	494	.3866	783							168
"	1140	"		"	26AB	S	30.2	31.0		#15	14.2	13.9	17.0	520	.3295	634							167
"	1445	"		"	27AB	S	32.4	29.2		#21	18.5	18.2	"	646	.3421	530							172
6	1520	BB		D49	28AB	S	29.2	26.8		#24	19.8	19.5	17.0	590	.3049	517							173
					AE																		179

* coarse material

Computed by [signature] Date 22/12/71 Checked by C.K. K Date 23/12/71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 207 (9–67)

Suspended Sediment Analysis Results

Stream ATHABASCA RIVER AT EMBARRAS AIRPORT for year 19 71.

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JLY					AE																		
17	1200	DK		D49	29AB	S	15.6	15.6		#5	17.4	17.1	63	550	.5563	1011	.0053	.0501	91	9.0	42.0	49.0	185
"	1400	"		"	30AB	"	14.4	16.6		#10	24.2	23.9	"	543	.7135	1314	.0080	.1641	302	23.0	37.0	40.0	193
"	1505	"		"	31AB	"	15.5	14.6		#15	25.0	24.7	"	651	1.0015	1540	.0104	.3105	477	31.0	35.0	34.0	197
"	1615	"		"	32AB	"	15.6	16.4		#21	27.3	27.0	"	634	.7362	1161	.0062	.1031	163	14.0	41.0	45.0	192
17	1650	DK		D49	33AB	S	15.4	16.6		#24	28.6	28.3	63	661	.7934	1200	.0060	.1269	192	16.0	38.0	46.0	185
AUGUST					AE																		
3	1735	DK		D49	34AB	M	21.0	21.0		#21	15.3	15.0	65	691	.1857	269							168
17	1755	DK		D49	35AB	M	17.4	17.4		#21	13.1	12.8	66	506	.0833	165							169
31	1145	BB		D49	36A B	M	20.2	22.2		#21	10.7	10.4	65.5	632	.0547	87							176
SEPTEMBER					AE																		
29	1040	BB	4.87	DH59	37AB	M	21.0	24.2		#21	9.8	9.5	44	454	.0236	52							188
DEC.					AE																		
8	1315	DK		DH58	38AB	M	34.0	31.4		150	12.1	11.8	32	431	.0016	4							252
					AE																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream BARIL LAKE for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number BL	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JULY 20	1100	DRG	3.25	HAND	1A					#12	3.25	3.0		408	.1062	260							307
"	1100	'	"		1B					"	"	3.0		452	.1431	317							308
"	1105	'	"		2A					"	"	1.5		402	.1258	313							307
"	1105	'	"		2B					"	"	1.5		458	.1396	305							299
20	1110	DG	3.25		3AB					#12	3.25	TOP		914	.2772	303							300
OCTOBER					BL4	Bed	material																
23		DG		INST	5AB					#12	2.0	1.9	35	836	.2342	280	-	.0023	3	1.0	15.0	84.0	326
"					6AB					"	"	1.0	"	893	.1703	191	-	.0017	2	1.0	3.0	96.0	326
23					7AB					#12	2.0	SURF	35	924	.1842	199	-	.0018	2	1.0	3.0	96.0	318
					BL8	Bed	material																

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R 287
(9—67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH—WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream BIG POINT CHANNEL - 1 MILE BELOW GOOSE ISLAND for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					BP																		
8	1711	BYB	4.63	D49	1AB	M	36.0	34.8	440	300	25.0	24.7	53	618	.5082	822							148
JUNE					BP																		
2	1530	BYB	2.15	D49	2AB	M	33.8	32.4		300	23.0	22.7	65	684	.0617	90							177
17	1020	"		"	3AB	S	34.6	32.8		400	27.7	27.4	62.5	627	.8553	1364	.0088	.0428	68	5.0	62.0	33.0	182
"	1030	"		"	4AB	"	32.8	30.6		350	27.2	26.9	"	717	.9680	1350							175
"	1035	"		"	5AB	"	29.8	30.0		300	28.0	27.7	"	638	.9993	1566							177
"	1040	"		"	6AB	"	28.4	30.2		225	21.5	21.2	"	586	.9220	1573							175
17	1040	BYB		D49	7AB	S	27.0	29.6		150	14.4	14.1	62.5	496	.8440	1702							161
JULY					BP																		
7	1740	BB	5.57	D49	8AB	S	26.2	26.8		300	26.8	26.5	62.5	618	.4278	692	.0155	.0941	152	22.0	49.0	29.0	168
19	1430	DK		"	9AB	S	21.0	20.8		400	25.0	24.7	66	509	.5083	999	.0117	.0915	180	18.0	48.0	34.0	181
"	1445	"		"	10AB	S	25.8	23.4		350	29.8	29.5	"	688	.8271	1202	.0177	.2068	301	25.0	48.0	27.0	180
"	1530	"		"	11AB	S	22.8	21.4		300	26.7	26.4	"	603	.6387	1059	.0150	.1533	254	24.0	44.0	32.0	184
"	1535	"		"	12AB	S	19.4	18.0		225	22.1	19.8	"	568	.6891	1213	.0187	.1929	340	28.0	44.0	28.0	181
19	1540	DK		D49	13AB	S	17.0	18.4		150	17.8	17.5	66	495	.5934	1199	.0170	.1721	348	29.0	41.0	30.0	180
AUGUST					BP																		
5	1035	DK		D49	14AB	M	23.2	24.6		300	25.0	24.7	72	707	.1825	258							181
19	1100	DK		D49	15AB	M	22.0	23.2		300	24.0	23.7	66	589	.0836	142							182
SEPTEMBER					BP																		
1	1550	BB		D49	16AB	L	22.6	23.0		300	21.3	21.0		649	.0424	65							174
30	1530	BB		DH59	17AB	M	32.4	36.0		300	21.3	21.0		576	.0237	41							180
DEC.					BP																		
21	1245	DK		GRAB	18A					200			32	383	.0002	1							267
21	1245	DK		GRAB	18B					200			32	440	.0017	4							---
					BP																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

(9–67)

Suspended Sediment Analysis Results

Stream ~~Athabasca~~ - Big Point Channel - 1mile below Goose Island for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
October 22					AB		28	25		280				724	.0174	24							193

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 267
(9–67)

Suspended Sediment Analysis Results

Stream QUATRE FOURCHES - FOUR FORKS for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time	Intake Time	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					QF		A	B		#													
3	1110	DG	4.44	DH59	1 AB	M	35.4	36.4		120	10.9	10.5	70	631	.0136	22							282
"		LO	"	"	2 AB	"	40.2	37.0		200	10.8	10.4	"	687	.0159	23							235
"			"	"	3 AB	"	32.0	32.6		280	10.0	9.6	"	583	.0119	20							230
"			"	"	4 AB	"	35.6	38.6		340	9.7	9.3	"	626	.0131	21							259
"			4.44	DH59	5 AB	M	35.2	39.6		440	7.9	7.5	70	526	.0113	22							267
3					QF6 to QF 12 Bed Material																		
6	1301	LO	4.38	P61	13AB	M	31.2	35.8	500	280	10.7	10.1	58	536	.0695	130							200
8	1100	GE	4.52	CR151	14AB	*	30.6	27.4	495	"	9.9			518	.0604	117							197
10	1500	LO	4.22	CR151	15AB		35.0	33.0	500	"	9.9			580	.0173	30							268
11	1355	BG		P61	16AB		33.0	49.4	500	"	10.3		63	640	.0089	14							196
14	1435	GE	4.95	CR151	17AB		34.0	35.0	505	280	10.3	10.0	64	572	.1212	212							165
15	1405	GE	5.54	CR151	18AB	*	54.0	56.0		MS	11.2	10.7		621	.1681	271							157
16	1450	BS	5.50	CR151	19AB	*	48.0	42.0		MS	10.7	10.0	65	693	.0340	49							165
18	1335	GE	5.04	CR151	20AB	#	28.8	30.0	505	280	10.5	10.0		674	.0658	98							121
21	1410	BG	5.16	"	21AB	*	22.4	**	505	75	10.1		64	373	.1183	317							154
"	1415	"	"	"	22AB	#	21.0	**	"	155	12.1		"	278	.0874	314							149
"	1422	"	"	"	23AB	#	20.2	**	"	235	10.6		"	279	.0914	328							148
"	1425	"	"	"	24AB	#	21.0	**	"	315	10.2		"	272	.0939	345							144
21	1427	BG	5.16	"	25AB	#	21.0	**	505	405	8.7		64	267	.0973	364							145
23	1400	GE		"	26AB		19.6	19.8	500	280	12.8	12.4		655	1.0333	1578	.0091	.0310	47	3.0	64.0	33.0	170
25	1420	BG	5.28	"	27AB	#	30.0	28.8	510	280	12.3	11.5	61	576	.5005	869							186
28	1115	GE	* 5.50	"	28AB	#	38.4	38.0		"	11.5	11.0		637	1.4015	2200	-	-	-	-	16.0	84.0	175
30	1055	GE	* 5.30	CR151	29AB	#	58.4	58.0	505	280	10.9	10.4		603	.7100	1177							166

#MS-Mid stream

* DH59R2

* Approximations

DH59R1

** B sample not taken

Computed by [signature] Date 8-11-71 Checked by [signature] Date 10-11-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH-WATER SURVEY OF CANADA

R 347
(9-67)

Suspended Sediment Analysis Results

Stream QUATRE FOURCHES AT FOUR FORKS for year 19 71

Date	Time	Observer	Water Level	* Type of Sampler	Sample Number	* Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JULY					QF																		
2	1405	GE		CR15	30AB		26.4	27.0	505	280	11.3	10.8		663	.4831	729							163
5	1515	GE		"	31AB		25.6	28.8	500	300	11.4	10.9		694	.5810	837							161
7	1440	BG		"	32AB		41.8	41.4	"	280		10.5	61	543	.6488	1195							177
12	1430	BS		"	33A		56.0		"	"	10.7	10.0		352	.0590	168							165
12	1435	BS		"	33B			74.0	"	"	10.7	10.0		261	.0425	163							—
14	1520	GE	5.28	"	34AB		38.8	35.1	"	"	11.2	10.5		691	.2396	347							167
16	1040	BS	5.91	"	35AB		22.0	21.0	"	"	12.1	11.5		659	.6826	1036							167
19	1540	GE		"	36AB		19.7	20.1	500	"	13.0	12.5		629	1.4046	2233	.0053	.0140	22	1.0	51.0	48.0	176
21	1415	BS	3.95	"	37AB	M	20.6	20.4	510	"	12.5	12.0		542	1.3991	2581	.0030	.0140	26	1.0	37.0	62.0	181
26	1135	GE	3.65	"	38A	"	27.3		"	"	12.2	11.6		354	.0329	93							185
26	1140		3.65	"	38B	"		62.5	"	"				*374	.0353	94							180
28	1050	BS	3.58	"	39AB	M	32.4	31.3	"	"	12.5	11.5		548	.0918	168							183
30	1130	GE	3.37	CR15	40AB	M	46.0	46.0	510	280	11.9	11.4		692	.0362	52							184
AUGUST					QF																		
3	1525	GE	3.47	CR15	41AB	L	22.0	24.8	510	280	12.8	12.2		557	.0395	68							175
11	1115	BS	2.98	CR15	42AB	L	19.8	18.8	510	280	11.7	11.0		636	.0505	79							180
16	1500	BS	2.81	DH59	43AB	M	27.0	27.0	500	280	11.6	11.0	65	695	.2150	309	.0177	.0301	43	14.0	72.0	14.0	161
18	1115	GE	2.66	DH59	44AB	M	26.4	28.3	505	"	11.4	10.8		638	.0426	67							169
20	1155	BC	2.56	CR15	45AB	R2	16.0	19.3	505	280	12.0	11.5		741	.1703	230							179
23	1200	GE	1.90	CR15	46AB	R1	40.5	43.0	490	140	11.1	10.9		754	.1825	242	.0056	.0055	7	3.0	50.0	47.0	182
"	1208	"	"	DH59	47AB	"	36.8	37.2	"	220	11.7	11.1		**806	.2246	279							189
"	1216	"	"	"	48AB	"	29.8	30.7	"	280	10.9	10.4		745	.2133	286							196
"	1225	"	"	CR15	49AB	"	31.1	31.3	490	360	10.6	10.1		689	.2198	319							199
23	1235	GE	1.90	DH59	50AB	R1	34.7	33.3	490	440	9.1	8.6		684	.2171	317							190
					QF																		
				* DI		* Refer R250								** Too full									
														* Leak around bottle									

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH—WATER SURVEY OF CANADA

R 387
(9—67)

Suspended Sediment Analysis Results

Stream QUATRE FOURCHES AT FOUR FORKS for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
SEPTEMBER					QF																		
3	1145	SF	2.25	DH59	51AB	L"	23.2	21.8		280	10.7	10.2		738	.1140	154							175
9	1150	"	1.27	"	52AB	"	20.8	22.8	485	"	10.2	10.0	56	739	.1375	186							255
16	1540	SF	3.75	"	53AB	"	20.4	19.6	495	280	10.0	9.8	50	735	.3998	544	.0020	.0040	5	1.0	30.0	69.0	267
21	1140	RK	3.41	"	54AB	"	22.8	21.4	485	140	10.2	10.0	44	673	.1851	275	-	.0019	3	1.0	26.0	73.0	259
"		"	"	"	55AB	"	20.6	18.8	"	200	10.2	10.0	"	619	.2525	408	.0020	.0101	16	4.0	27.0	69.0	298
"	1200	"	"	"	57AB	"	18.2	19.2	"	280	9.6	9.4	"	666	.2019	303	-	.0020	3	1.0	27.0	72.0	262
"	1210	"	"	"	57AB	"	17.0	16.4	"	360	8.8	8.6	"	646	.2731	423	-	.0027	4	1.0	23.0	76.0	301
21	1215	RK	3.41	DH59	58AB	L	18.6	19.0	485	440	7.1	6.9	44	733	.1917	262	.0042	.0038	5	2.0	41.0	57.0	243
				QP 59	to QF 69 Bed material																		
24	1120	WH		DH59	70AB	L	19.8	19.0	490	280	10.6	10.4	46	698	.3399	487							188
27	1500	DG	3.01	:	65AB	L	24.8	23.2	480	"	9.0	8.8	40	767	.3014	393							235
29	1200	RK	5.14	DH59	66AB	L	19.8	18.0	475	280	8.7	8.5	37	622	.8106	1303	.0050	.0243	39	3.0	47.0	50.0	366
OCTOBER					QF																		
12	1545	DG	4.46	DH59	67AB	L		22.8	462	280	7.0	6.8		747	1.3506	1808	.0076	-	-	-	60.0	40.0	409
18		SF		DH59	68AB	L	23.0	25.8		280				619	.5363	866							381
					QF																		

Numbers QF65 to QF68 duplicated.

Computed by ______ Date ______ Checked by ______ Date 22/12/71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream EMBARRAS RIVER - 2¼ MILES BELOW DIVERSION- for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					E																		
9	1715	JCD	4.00	D49	1AB	M	21.0	15.6	313	215	14.7	14.3	53	571	.2532	443							148
JUNE																							
3	1645	JCD	-0.02	D49	2AB	M	29.0	29.2		240	12.0	11.7	69	575	.0849	148							188
15	1730	"		"	3AB	"	23.0	23.6		420	15.3	15.0	62	565	.6788	1201	.0087	.0407	72	6.0	59.0	35.0	167
"	1750	"		'	4AB	"	21.6	23.6		360	17.3	17.0	"	629	.8415	1338	.0100	.0842	134	10.0	57.0	33.0	154
"	1805	"		"	5AB	"	20.6	19.6		300	16.3	16.0	"	696	1.0004	1437	.0116	.1701	244	17.0	52.0	31.0	177
"	1835	"		"	6AB	"	16.0	15.4		200	13.1	12.8	"	585	.8032	1373	.0117	.1205	206	15.0	53.0	32.0	164
15	1845	JCD		D49	7AB	M	16.4	17.2		100	12.0	11.7	62	515	.6480	1258	.0095	.0518	101	8.0	60.0	32.0	176
JULY					E																		
7	0830	JD	7.84	D49	8AB	M	22.8	22.6		360	15.4	15.1	62.5	618	.3299	534	.0100	.0396	64	12.0	55.0	33.0	183
18	1050	DK		D49	9AB	S	22.6	22.2		100	17.1	16.8	63	491	.5020	1022	.0103	.2008	409	40.0	20.0	40.0	195
"	1100	"		"	10AB	"	20.0	21.0		200	17.3	17.0	"	513	.5334	1040	.0068	.1280	250	24.0	32.0	44.0	183
"	1105	"		"	11AB	"	23.6	23.8		300	20.1	19.8	"	568	.5581	983	.0068	.1284	226	23.0	33.0	44.0	188
"	1110	"		"	12AB	"	22.8	24.2		360	22.1	21.8	"	547	.4915	899	.0058	.0885	162	18.0	35.0	47.0	183
18	1115	DK		D49	13AB	S	22.6	25.0		400	20.5	20.2	63	490	.4212	860	.0052	.0632	129	15.0	36.0	49.0	182
AUGUST					E																		
4	1240	DK	4.14	D49	14AB	M	16.0	16.6		240	8.0	7.7	71	483	.1591	329							174
18	1145	DK	1.88	D49	15AB	M	19.4	20.0		240	5.7	5.4	66	537	.0993	185							179
31	1540	DK		D49	16AB	M	16.0	15.8		240	3.4	3.1	60	602	.9371	62							186
Dec.					E																		
20	1455	BB		GRAB	17A					100	5.7			424	.0026	6							292
20	1455	BB		GRAB	17B					100	5.7			411	.0023	6							---
					E																		

Computed by C. Roy Date 23/12/71 Checked by C.K.K. Date 14/1/72

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream FLETCHER CHANNEL BELOW DIVERSION for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					FC																		
8	1110	BYB	4.75	D49	1AB	M	37.2	39.2	310	240	16.3	16.0	52	561	.3312	590							157
JUNE					FC																		
3	1215	BYB	1.70	D49	2AB	M	25.2	25.2		270	17.7	17.4		661	.0938	142							186
16	1025	"		"	3AB	M	20.6	21.0		320	18.1	17.8	62	695	1.1856	1706							162
"	1040	"		"	4AB	S	28.2	24.8		270	17.8	17.5	62	551	.9539	1731							167
"	1050	"		"	5AB	S	30.0	27.8		230	17.0	16.7	62.5	610	1.1980	1964							162
"	1110	"		"	6 AB	M	19.0	17.6		150	8.1	7.8	62.5	709	1.3910	1962							163
16	1125	BYB		D49	7AB	M	18.0	18.0		90	6.5	6.2	62.5	663	1.2054	1818							166
JULY					FC																		
7	1340	BYB		D49	8AB		17.6	16.8		270	17.5	17.2	63	581	.5032	866	.0265	.1962	338	39.0	41.0	20.0	169
18	1715	"		"	9AB	S	22.8	23.0		90	13.8	13.5	64	506	1.1032	2180	.0290	.3972	785	36.0	40.0	24.0	187
"	1720	"		"	10AB	"	26.4	22.8		150	16.4	16.1	"	639	1.3648	2136	.0320	.5459	854	40.0	36.0	24.0	190
"	1730	"		"	11AB	"	22.8	23.6		230	19.0	18.7	"	640	1.1145	1741	.0200	.4124	644	37.0	36.0	27.0	187
"	1735	"		"	12AB	"	18.4	18.6		270	21.3	21.0	"	626	1.0181	1626	.0143	.2851	455	28.0	40.0	32.0	188
18	1745	BYB		D49	13AB	S	19.6	19.6		320	21.8	21.5	64	523	.8094	1548	.0140	.1862	356	23.0	44.0	33.0	177
AUG					FC																		
4	1520	JCD		D49	14AB	M	22.0	24.0		270	18.4	18.1	70	628	.2186	348	.0197	.0525	84	24.0	57.0	19.0	159
18	1445	JCD		D49	15A B	M	20.0	20.6		270	17.8	17.5	66	516	.0835	162							165
					FC																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 387
(9–67)

Suspended Sediment Analysis Results

Stream FLETCHER CHANNEL BELOW DIVERGENCE for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
SEPTEMBER					FC																		
1	1040	BB		D49	16AB	M	21	26		270	16.2	15.9	65.5	495	.0395	80							174
29	1100	BB		DH59	17AB	M	23.2	30.2		270	13.0	12.7	44.5	471	.0329	70							172
DEC.					FC																		
20	1300	BB		DH58	18AB	L	36.2	42.4		260	10.4	10.1	32	336	.0020	6							280
					FC																		

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R 307
(9–67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream Fletcher Channel for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
October 22			1.06		AB		32	29		240				729	.0202	28							191

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

(9–67)

Suspended Sediment Analysis Results

Stream Embress (Embarras River - 2¼ Miles below Diversion) for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
October ober 23					AB		24	27		240				594	.0095	16							210

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 267
(9–67)

Suspended Sediment Analysis Results

Stream GOOSE ISLAND CHANNEL - ½ MILE BELOW DIVERSION for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					GI																		
8	1348	BYB	3.29	D49	1AB	M	34.0	32.8	326	160	21.1	20.8	53	606	.6567	1084							150
JUNE																							
2	1745	BYB	1.00	D49	2AB	M	30.8	29.0		150	22.0	21.7	68	599	.0657	110							181
16	1750	"	3.96	"	3AB	S	28.8	29.0	328	50	18.8	18.5	63	528	.8428	1596							175
"	1755	"	"	"	4AB	"	32.0	33.0	"	110	28.3	28.0	"	648	1.1603	1791							172
"	1800	"	"	"	5AB	"	31.6	32.0	"	150	27.5	27.2	"	649	1.2073	1860							168
"	1805	"	"	"	6AB	"	28.2	28.0	"	210	21.7	21.4	"	587	Sample	destroyed							180
16	1815	BYB	3.96	D49	7AB	S	26.0	25.0	328	270	18.0	17.7	63	506	.9432	1864							164
JULY					GI																		
7	1600	JD	4.25	D49	8AB	S	28.0	29.8	328	150	26.7	26.4	63	601	.5250	874	.0270	.2048	341	39.0	40.0	21.0	180
19	1815	BB		"	9AB	"	20.6	23.6	332	295	12.9	12.6	66	513	.6335	1235	.0193	.1901	371	30.0	42.0	28.0	170
"	1825	"		"	10AB	"	25.0	23.0	"	220	23.5	23.2	"	667	.9180	1376	.0298	.3580	537	39.0	38.0	23.0	186
"	1835	"		"	11AB	"	22.4	23.6	"	145	24.5	24.2	"	718	.9243	1287	.0260	.3143	438	34.0	43.0	23.0	206
"	1845	"		"	12AB	"	21.8	21.6	"	95	30.2	29.9	"	717	.8575	1196	.0215	.2658	371	31.0	43.0	26.0	189
19	1850	BB		D49	13AB	S	21.8	21.6	332	45	27.1	26.8	66	544	.7416	1363	.0228	.2225	409	30.0	44.0	26.0	184
AUGUST					GI																		
4	1745	DK		D49	14AB	M	24.6	23.0		150	25.7	25.4	70	697	.2292	329	.0160	.0550	79	24.0	56.0	20.0	183
18	1700	DK	2.82	D49	15AB	M	31.0	29.0		150	24.0	23.7	66	731	.1685	231							169
SEPTEMBER					GI																		
1	1320	BB	1.26	D48	16AB	M	27.5	27.2		150	24.0	23.7	65	743	.0520	70							179
30	1400	BB	0.20	DH59	17AB	M	38.8	39.6		150	21.6	21.3	45	666	.0275	41							173
DEC.					GI																		
21	[illegible]	DH		GRAB	18A					DAILY			32	452	.0023	5							265
21	1330	DH		GRAB	18B					DAILY			32	452	.0033	7							---
					GI																		

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R 267
(9–67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream HARRISON RIVER ABOVE OLD FORT BAY for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					HAR																		
5	1105	LAW	1540	DH48	1AB	M				38'RB				726	.0237	33							64

Computed by [illegible] Date [illegible] 22/71 Checked by [illegible] Date 14-12-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 387
(9–67)

Suspended Sediment Analysis Results

Stream LAKE ATHABASCA for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	°F Temperature	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					LA																		
30	0630	DRG		INST	1AB					#1	8.4	6.7		782	.1231	157							94
"	0640	"		"	2AB					#1	"	4.2		762	.1211	159							89
"	0650	"		"	3AB					#1	8.4	SFC		899	.1304	145							176
"	0700	"		"	4AB					#2	11.7	11.0		790	.1272	161							141
"	0710	"		"	5AB					#2	"	5.8		757	.1173	155							139
"	0720	"		"	6AB					#2	11.7	SFC		923	.1464	159							132
"	0730	"		"	7AB					#3	7.5	7.0		756	.1121	148							118
"	0740	"		"	8AB					#3	"	3.7		772	.1111	144							113
"	0750	"		"	9AB					#3	7.5	SFC		913	.1287	141							104
"	0830	"		"	10AB					#4	14.8	14.0		762	.1457	191							138
"	0840	"		"	11AB					#4	"	7.0		777	.1002	129							146
"	0850	"		"	12AB					#4	14.8	SFC		906	.1099	121							153
"	0900	"		"	13AB					#5	7.8	6.6		710	.1029	145							129
"	0910	"		"	14AB					#5	"	3.9		789	.1091	138							130
30	0920	DRG		INST	15AB					#5	7.8	SFC		899	.1185	132							130
JULY					LA																		
17	1200	DRG		INST	16AB					#1A	29.5	28.0	64	745	.0097	13							065
"	1205	"		"	17AB					#1A	"	14.5		759	.0064	8							064
"	1210	"		"	18AB					#1A	29.5	TOP		795	.0064	8							061
"	1350	"		"	19AB					#2A	20.5	19.0		742	.0632	85							082
17	1400	DRG		INST	20AB					#2A	20.5	9.5		702	.0489	70							090
					LA																		

Computed by [illegible] Date 29/7/71 Checked by [illegible] Date 14-12-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 807
(9–67)

Suspended Sediment Analysis Results

Stream LAKE ATHABASCA for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JULY					LA																		
17	1410	DRG		INST	21AB					#2A	20.5	TOP		886	.0558	63							090
"	1620	"		"	22AB					#3A	13.5	11.5		733	.0610	83							124
"	1625	"		"	23AB					"	"	6.7		749	.0615	82							125
"	1630	"		"	24AB					#3A	13.5	TOP		889	.0713	80							122
"	1645	"		"	25AB					#4A	8.5	7.5		685	.0663	97							139
"	1650	"		"	26AB					"	"	4.5	64	745	.0566	76							124
"	1700	"		"	27AB					#4A	8.5	TOP		845	.0641	76							132
"	1730	"		"	28AB					#5A	8.9	7.0		707	.2114	299							151
"	1735	"		"	29AB					"	"	3.5		753	.2190	291							156
"	1740	"		"	30AB					#5A	8.9	TOP		682	.2010	295							152
"	1800	"		"	31AB					#6A	21.9	20.9		648	.1500	231							160
"	1805	"		"	32AB					"	"	11.0		759	.1641	216							158
"	1810	"		"	33AB					#6A	21.9	TOP		674	.1451	215							153
"	1820	"		"	34AB					#7A	9.5	8.0		746	.2624	352							165
"	1825	"		"	35AB					"	"	4.0		791	.2032	257							151
17	1830	DRG		INST	36AB					#7A	9.5	TOP		868	.2000	230							175
					LA37 to LA43 Bed Material																		

Computed by [illegible] Date 25/11/71 Checked by [illegible] Date 14-12-71

R 297
(9-67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream LAKE ATHABASCA for year 19 71

Date JULY	Time	Observer	Water Level	Type of Sampler	Sample Number LA	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
29		BS		INST	44AB					#8A	8.8	7.8	68	744	.1275	171							173
"		"		"	45AB					"	"	4.0		706	.0564	80							170
"		"		"	46AB					#8A	"8.8	TOP		708	.0521	74							169
"		"		"	47AB					#9A	10.4	9.5		725	.0883	122							165
"		"		"	48AB					"	"	4.5		703	.0705	100							170
"		"		"	49AB					#9A	10.4	TOP		717	.0620	87							161
"		"		"	50AB					#10A	10.5	9.5		733	.0842	115							161
"		"		"	51AB					"	"	5.0		727	.0815	113							159
"		"		"	52AB					#10A	10.5	TOP		757	.0761	101							164
"		"		"	53AB					#11A	12.5	11.5	68	764	.0765	100							163
"		"		"	54AB					"	"	6.0		719	.0700	97							162
"		"		"	55AB					#11A	12.5	TOP		680	.0590	87							166
"		"		"	56AB					#12A	13.0	11.5		743	.0737	99							161
"		"		"	57AB					"	"	6.0		721	.0716	99							162
29		BS		INST	58AB					#12A	13.0	TOP		677	.0594	88							164
				LA59 to LA63 Bed Material																			

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

(9–67)

Suspended Sediment Analysis Results

Stream LAKE ATHABASCA for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
OCTOBER					LA																		
19	1015			INST	64A					8A	4.2	3.6		357	.0096	27							196
"				"	64B					"	"	3.6		425	*.0165	39							-
"				"	65AB					"	"	2.1		783	.0133	17							191
19				INST	66AB					8A	4.2	Surf		779	.0107	14							187
					LA67 Bed material																		
19	1040			INST	68AB					9A	6.0	5.4		578	.0309	53							193
"				"	69AB					"	"	3.0		785	.0478	61							192
19				INST	70 AB					9A	6.0	Surf		780	.0407	52							191
					LA71 Bed material																		
19	1130			INST	72AB					10A	7.5	6.9		557	.0350	63							177
"				"	73AB					"	"	3.7		575	.0365	63							175
19				INST	74AB					10A	7.5	Surf		832	.0504	61							174
					LA75 Bed material																		
19	1145			INST	76AB					11A	8.5	7.9		676	.1080	160							119
"				"	77A					"	"	4.3		450	*.0345	77							109
"				"	77B					"	"	4.3		337	.0260	77							-
19				INST	78AB					11A	8.5	Surf		769	.0580	75							111
					LA79 Bed Material																		
19	1210			INST	80AB					12A	9.4	8.8		781	.0542	69							104
"				"	81AB					"	"	4.7		656	.0440	67							-
19				INST	82AB					12A	9.4	Surf		692	.0423	61							105
					LA83Bed material																		
19	1345			INST	84A					2A	17.6	17.0		281	*.0193	69							69
"				INST	84B					"	"	17.0		457	.0152	33							-
"				"	85AB					"	"	8.3		772	.0259	34							67
19				INST	86AB					2A	17.6	Surf		772	.0180	23							64
					LA87 Bed material																		

* coarse material

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 387
(9–67)

Suspended Sediment Analysis Results

Stream LAKE ATHABASCA for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
OCTOBER					LA																		
19	1425			INST	88AB					3A	16.0	15.4		723	.0328	45							65
"				"	89AB					"	"	7.7		772	.0292	38							63
19				INST	90AB					3A	16.0	Surf		773	.0275	35							64
					LA91 Bed Material																		
19	1500			INST	92AB					4A	10.4	9.8		607	.0190	31							62
"				"	93AB					"	"	4.9		723	.0167	23							59
19				INST	94AB					4A	10.4	Surf		832	.0160	19							60
					LA95 Bed material																		
19	1530			INST	96AB					5A	5.5	4.9		743	.0481	65							64
"				"	97AB					"	"	2.5		770	.0531	69							62
19				INST	98AB					5A	5.5	Surf		774	.0462	60							62
					LA99 Bed material																		
19	1600			INST	100AB					6A	17.0	16.4		789	.1080	137							74
"				"	101AB					"	"	8.2		777	.0916	118							78
19				INST	102AB					6A	17.0	Surf		782	.0889	114							71
					LA103 Bed material																		
19	1630			INST	104AB					7A	5.6	5.0		781	.0741	95							66
"				"	105AB					"	"	2.5		788	.0749	95							71
19				INST	106AB					7A	5.6	Surf		810	.0814	100							66
					LA107 Bed material																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream LAKE CLAIRE for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					LC																		
30	1115	DRG		INST	1AB					#7	3.3	2.9	68	790	.2554	323							298
30	1125	"		"	2AB					#7	3.3	SFC	"	908	.2926	322							292
30	1135	"		"	3A					#8	3.6	3.0	"	344	.0203	59							447
30	1140	DRG		INST	33					#8	3.6	3.0	68	439	.0280	64							443
JULY																							
21	0925	DRG		INST	4AB					#7	4.2	3.7	68	623	.1128	181							396
"	0930	"		"	5AB					"	4.2	2.1	"	734	.1210	165							400
"	0935	"		"	6AB					#7	4.2	Top	"	894	.1568	175							404
"	1000	"		"	7AB					#8	2.8	2.4	"	692	.2754	398							463
"	1005	"		"	8AB					"	2.8	1.4	"	661	.2506	379							457
"	1010	"		"	9AB					#8	2.8	Top	"	892	.3336	374							462
"	1030	"		"	10AB					#9	2.3	2.2	"	675	.1904	282							191
"	1035	"		"	11AB					"	2.3	1.1	"	912	.2604	286							191
21	1040	DRG		INST	12AB					#9	2.3	Top	68	908	.2517	277							194

LC 13 to 15 Bed Material

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R 307
(9–67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream LAKE CLAIRE for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
OCTOBER					LC																		
22	1000	DG		INST	16AB					#9	2.0	1.8	2.0	662	.4892	739	- -	.0049	7	1.0	15.0	84.0	364
"		"		"	17AB					"	"	1.0	"	618	.4604	745	- -	.0046	7	1.0	18.0	81.0	357
22		DG		INST	18AB					#9	2.0	Surf	2.0	887	.6527	736	- -	- -	- -	- -	19.0	81.0	361
					LC19 Bed material																		
22	1030	DG		INST	20AB					#7	3.6	3.4	2.0	706	.3556	504	- -	.0036	5	1.0	24.0	75.0	421
"		"		"	21AB					"	"	1.8	"	656	.3308	504	- -	- -	- -	- -	19.0	81.0	417
22		DG		INST	22AB					#7	3.6	Surf	2.0	865	.4402	509	- -	- -	- -	- -	19.0	81.0	407
					LC23 Bed material																		
22	1100	DG		INST	24AB					#8	2.2	1.9	2.0	712	.3312	465	- -	- -	- -	- -	28.0	72.0	452
"		"		"	25AB					"	"	1.1	"	688	.3237	470	- -	- -	- -	- -	25.0	75.0	457
22		DG		INST	26AB					#8	2.2	Surf	2.0	847	.3836	453	- -	.0038	5	1.0	25.0	74.0	466
					LC27 Bed material																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 207
(9–67)

Suspended Sediment Analysis Results

Stream LAKE MAMAWI for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					ML																		
30	1045	DRG		INST	1AB					6	2.0	1.8	78	785	.4038	514							168
30	1055	DRG		INST	2AB					6	2.0	S FC	78	910	.4285	471							170
JULY					ML																		
20	1155	DG		INST	3AB					10	3.0	3.0	70	839	.2483	296							173
"	1200	"		"	4AB					"	"	1.5	"	868	.2459	283							174
"	1210	"		"	5AB					10	"	TOP	"	897	.2442	272							175
"	1300	"		"	6AB					11	"	2.5	"	907	.0750	83							197
"	1305	"		"	7AB					"	"	1.5	"	789	.0563	71							205
20	1310	DG		INST	8AB					11	3.0	TOP	70	860	.0699	81							233
			ML9	and	ML1C bed material																		
OCTOBER					ML																		
23		DG		INST	11AB					11	1.6	1.5	35	929	.3650	393		.0146	16	4.0	7.0	89.0	365
"		"		"	12AB					"	"	0.8	"	916	.3248	355		.0032	4	1.0	4.0	95.0	371
23		DG		INST	13AB					11	1.6	Surf	35	931	.3220	346		.0032	3	1.0	7.0	92.0	365
					ML14 Bed material																		
23		DG		INST	15AB					10	1.4	1.3	35	902	.3469	385		.0069	8	2.0	12.0	86.0	374
"		"		"	16AB					"	"	0.7	"	924	.2860	310		.0029	3	1.0	8.0	91.0	364
23		DG		INST	17AB					10	1.4	Surf	35	884	.2703	306		.0027	3	1.0	5.0	94.0	374
					ML18 Bed material																		

Computed by ______ Date ______ Checked by ______ Date ______

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 207
(9–67)

Suspended Sediment Analysis Results

Stream MAMAWI CHANNEL for year 19 71.

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	* Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					MC																		
3	1510	DG	4.64	DH59	1AB	L	54.0	54.0		200	16.9	16.7	68	637	.0230	36							394
21	1057	PV	5.15	CR151	2A		30.0		375	335	9.6	9.0	71	180	.0157	87							166
"	1100	"	"	" "	3A		42.0		"	275	17.0	16.0	"	246	.0248	101							155
"	1115	"	"	" "	4A		41.5		"	215	17.6	16.5	"	240	.0231	96							148
"	1120	"	"	" "	5A		42.4		"	165	15.2	14.0	"	244	.0207	85							162
21	1125	PV	5.15	"	6A		42.5		"	115	8.2	7.5	71	273	.0182	67							175
23	1635	LO	6.63	"	7AB	RIM	23.2	19.8	"	200	18.6	18.0	68	599	1.0871	1815	.0124	.0109	18	1.0	74.0	25.0	143
25	1100	BS	5.80	"	8AB	"	31.2	22.0	375	200	17.8	17.0	62	539	.5004	928							181
28	1505	LO	5.44	"	9AB	"	39.4	36.0	370	220	17.7	17.0		665	.4306	648							172
30	0845	BS	5.48	CR151	10AB	RIM	56.0	62.4	370	200	17.0	16.5		650	.3251	500	–	.0033	5	1.0	3.0	96.0	173
JULY					MC																		
2	1600	BS	5.80	CR151	11AB	RIM	42.0	36.2	370	200	17.0	16.5		689	.5071	736							162
5	1210	GE	5.98	"	12AB	RIM	62.0	59.0	370	"	17.9	17.0		727	.4817	663							162
12	1125	BS	5.60	"	14AB		47.0	43.4	"	"	17.6	"		635	.1080	170							177
14	1145	GE	4.94	"	15AB		77.2	73.8	"	"	17.4	"		695	.2233	321							190
15	1410	BS	5.50	"	16AB		33.4	31.0	375	"	18.7	17.0		618	.8083	1307							187
18	1220	BG	6.18	"	13AB		55.6	60.4	375	"	17.4	"	61	564	.4845	859		–	–	–	10.0	90.0	180
19	1225	GE		"	17AB		45.4	43.0	385	"	18.9	18.4		711	1.1597	1645							187
21	1050	BS	6.38	"	18AB		32.0	24.4	385	"	19.0	18.0		730	2.0540	2814	.0037	.0205	28	1.0	42.0	57.0	192
26	1540	BG	6.88	"	19AB		38.0	37.6	390	"	18.9	18.5		640	.0683	107							193
28	1420	BS	5.72	"	20AB		36.4	40.0	390	200	18.3	17.5		568	.0667	117							192
30	1520	GE	5.74	CR151	21AB		48.4	50.0	385	200	18.2	17.6		728	.0506	70							190
AUGUST					MC																		
3	1150	GF	5.47		22AB					200				714	.2155	302	.0078	.0022	3	1.0	65.0	34.0	181
9	1730	BC	5.20		23AB					200				573	.0921	161							180
					Mc																		

* Refer R250

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R.257 (9–67)

Suspended Sediment Analysis Results

Stream MAMAWI CHANNEL AT DOG CAMP for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
AUGUST					MC																		
13	1620	GE	4.53	CR151	24AB	R2	22.3	21.6	380	Mid stream	17.1	16.5		796	.3806	478	.0056	.0076	10	2.0	51.0	47.0	193
18	1520	GE	4.88	"	25AB	R2	51.0	55.6	375	200	17.6	17.0		591	.0219	37							172
19	1710	BG	4.90	"	26AB	R1	37.5	42.1	375	"	17.5	17.0		528	.0646	122							176
24	1500	BS	4.26	CR151	27AB	R2	24.2	25.6	370	200	17.0	16.5		610	.0786	129							198
SEPTEMBER					MC																		
3	1410	FET	4.38	CR151	28AB	L	36.0	33.0	370	200	16.6	16.0		709	.0512	72							178
9	1410	FET	3.34	DH69	29AB	"	25.4	24.8	340	"	16.0	15.6	14.0	764	.2323	304							296
16	1230	FET	3.31	DH69	30AB	"	33.2	30.0	340	200	15.8	15.5	10.0	763	.7912	1037	.0041	.0079	10	1.0	43.0	56.0	371
21	1500	WH	3.08	DH59	31AB	"	29.2	30.4	325	100	12.1	11.9	6.5	642	.4004	624	.0022	- -	- -	- -	32.0	68.0	391
"	1515	"	"	"	32AB	"	31.2	31.6	"	160	16.2	16.0	"	718	.5208	725	.0027	- —	- -	- -	38.0	62.0	388
"	1525	"	"	"	33AB	"	32.8	30.2	"	200	16.0	15.8	"	732	.4185	572	- -	.0042	6	1.0	26.0	73.0	385
"	1530	"	"	"	34AB	"	29.2	28.6	"	240	15.4	15.2	"	676	.3535	523	- -	- -	- -	- -	21.0	79.0	393
21	1540	WH	3.08	DH59	35AB	L	26.4	25.2	325	280	10.7	10.5	6.5	681	.3731	548	— -	- -	- -	- -	20.0	80.0	382
					Mc36 to MC46 Bed material																		
24	1330	RK	4.00	DH59	47AB	L	25.0	24.0	355	200	17.1	16.9	6.5	636	.3333	524							188
27	1220	DG	2.70	"	47AB	"	23.6	24.6	304	"	15.5	15.2	4.5	645	.4148	643							243
29	1420	RK		DH59	48AB	L	22.4	24.4	320	200	15.6	15.4	4.0	634	.8647	1364	.0051	.0086	14	1.0	50.0	49.0	375
OCTOBER					MC																		
12	1400	HH	5.49	DH59	49AB	L	21.0	23.4	287	200	13.4	13.1		638	.0176	20							389
18		SF		DH59	50AB	L	24.8	25.2		200				617	.5950	964							384
					MC																		
					Number 47AB duplicated																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 267
(9–67)

Suspended Sediment Analysis Results

Stream McIVOR RIVER AT MOOSE HORN for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					MCI																		
4	1218	RMB	94.08	DH48	1AB	M	30.0	26.0		26'LB				571	.5119	896	.0035	.0154	27	3.0	38.0	59.0	247

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH - WATER SURVEY OF CANADA

R 867
(9-67)

Suspended Sediment Analysis Results

Stream OLD FORT NEAR MOUTH for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
MAY					OFT																		
4	1820	RMB	3.69	DH48	1AB	M	29.0	27.6		48'LB				620	.0367	59							107

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 387
(9–67)

Suspended Sediment Analysis Results

Stream PRAIRIE RIVER for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number PR	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mg/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mg/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mg/l)
JULY																							
29	1450	SF		DH59	001AB	L	29.4	22.5	320	100	8.5	8.5	68	687	.2000	291							198
"	1500	"		"	002AB	"	21.4	22.6	"	140	8.3	8.3	"	620	.1718	277							197
"	1510	"		"	003AB	"	23.4	25.0	"	200	8.5	8.5	"	647	.1867	289							198
"	1520	"		"	004AB	"	26.6	25.0	"	260	8.3	8.3	"	684	.1974	289							198
29	1530	SF		DH59	005AB	L	26.0	26.6	320	300	8.5	8.5	68	609	.1784	293							198
AUGUST																							
4	1330	BG		DH59	006AB	M	50.8	56.7	320	180	8.8	8.7		681	.2762	406	—	—	—	—	21.0	79.0	188
9	1340	BG		DH59	007AB	M	50.2	48.6	320	180	8.4	8.0		677	.2129	314							197
				PR	0011 to PR0017 Bed Material taken July 29																		
13	1345	GC	4.63	CR151	PR 0018AB	R2	40.2	54.5	310	200	8.7	8.4		686	.2564	374							203
17	1220	BG		"	0019AB	R1	46.0	42.4	325	"	8.7	8.4		732	.1229	168							192
19	1245	"		"	0020AB	R2	23.4	23.0	320	200	8.1	7.5		641	.0448	70							200
24	1300	"		"	0021A	R1	34.4		320	180	8.7	8.2		319	.0664	208							302
24	1305	BG		CR151	0021B	"		40.2	320	"	8.7	8.2		293	.0628	214							–
31	1300	SF	4.12	CR151	0022AB	R1	49.4	51.4	315	180	8.5	8.0	62	758	.0802	106							294
SEPTEMBER					PR																		
20	1500	SF	2.23	DH59	0023AB	L	31.0	27.8	315	100	7.9	7.5		640	.2483	388	—	.0025	4	1.0	5.0	94.0	378
"		"	2.22	"	0024AB	"			"	140	"	"		756	.2778	368	—	-	-	-	5.0	95.0	375
"		"	2.21	"	0025AB	"			"	200	"	"		745	.2787	374	—	-	-	-	4.0	96.0	378
"		"	2.20	"	0026AB	"			"	240	7.9	"		675	.2872	426	—	.0029	4	1.0	15.0	84.0	379
20		SF	2.19	DH59	0027AB	L			315	300	7.8	7.5		632	.2225	352	—	.0045	7	2.0	8.0	90.0	381
				PR	0028 to PR00234 Bed material																		

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 367
(9–67)

Suspended Sediment Analysis Results

Stream RICHARDSON LAKE for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	# Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .003 to .05mm	% Clay .003mm	Dissolved Solids (mgr/l)
AUGUST																							
10	0930	BS		INST	RL01AB					RN	3.5	3.0	67	716	.0052	7							
"	0935	"		"	RL02AB					"	"	1.5	"	639	.0011	2							151
"	0940	"		"	RL03AB					RN	3.5	TOP	"	679	0.0	0							148
"	1000	"		"	RL04AB					RS	4.0	3.5	"	715	.0680	95							148
"	1005	"		"	RL05AB					"	"	2.0	"	754	.0727	96							186
10	1010	BS		INST	RL06AB					RS	4.0	TOP	67	704	.0542	77							187
OCTOBER					RL07 and RL08 Bed material																		183
22	1130	DG		INST	ER09AB					#13	2.0	1.8	36	652	.1671	256							
"		"		"	ER10AB					"	"	1.0	"	614	.1536	250							201
22		DG		INST	LR11AB					#13	2.0	SURF	36	462	.0931	202							191
					LR12 Bed material																		191
22	1145	DG		INST	LR13AB					#14	1.8	1.6	36	586	.2186	373							
"		"		"	LR14AB					"	"	0.8	"	751	.2377	317							197
22		DG		INST	LR15AB					#14	1.8	Surf	36	449	.1474	328							194
					LR16 Bed material																		196

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DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream ROCHER RIVER - BEN HOULES CABIN for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
JUNE					RR																		
2	1050	DG		P61	1 AB	M	36.9	35.2		800	38.7	38.0	56	750	.1649	220							129
"		"		"	2AB	"	36.0	34.8		680	44.4	44.0	"	761	.0747	98							130
"		"		"	3A B	"	29.2	38.6		560	46.3	45.5	"	726	.1000	138							127
"		"		"	4AB	"	32.4	30.2		480	47.7	47.3	"	658	.0786	120							132
2	1130	DG		P61	5AB	M	32.0	34.6			33.5	33.0	56	514	.0715	139							125
					RR6	to	RR	16	BED	MATERI	AL												
3	1240	GE		P61	17AB		25.2	29.0		560	47.0			596	.0591	99							121
4	1510	"	4.40	"	18A		24.1			"	48.2		60	386	.0340	88							131
4	1520	"	4.40	"	18B			21.8		"	48.2		60	254	.0216	85							
5	1355	GE	5.70	"	19AB		25.2	24.2		"	47.4		58	690	.1038	150							126
7	1553	LO		"	20AB		25.4	24.9		"	47.1		59	597	.0971	163							161
8	1150	LO	4.72	"	21AB		22.8	24.3		"	47.7		62	563	.1161	206							148
9	1730	LO	4.78	"	22AB	M	24.8	24.2		"	47.7	47.2	59	585	.1334	228							128
10	1240	GE	4.28	"	23AB	"	29.6	33.0		"	47.6	47.0	59	647	.1556	240							136
11	1115	GE	4.30	"	24A	"	26.8			"	47.0	46.5	62	310	.0328	106							126
11	1120	GE	4.30	"	24B	"				"	47.0	46.5	62	292	.0299	102							
14	1515	BG	5.28	"	25AB	"	31.0	30.1		"	48.7	48.0	60	565	.1348	239							134
15	1500	BS	5.52	"	26AB	"	29.0	30.6		"	48.0	47.0	62	693	.1628	235							139
16	1435	GE	5.72	P61	27AB	"	30.4	30.0	1000	560	48.8	48.0		659	.1362	207							127
19	1245	BS	5.20	CR151	28AB	"	39.0	40.0		560	48.3	47.0		672	.3160	470	-	.0126	19	4.0	25.0	71.0	165
21	1325	LA	5.58	P61	29AB	"	44.4	40.6		360	42.9	42.0		582	.1274	219							159
"	1345	"	"	"	30AB	"	41.4	38.8		480	48.6	48.0		626	.1317	211							144
"	1355	"	"	"	31AB	"	44.5	37.2	1010	600	47.7	47.3		615	.1243	202							162
"	1405	"	"	"	32AB	"	37.4	39.2	"	720	45.0	44.7		565	.1230	218							161
21	1415	LA	5.58	P61	33AB	M	38.0	36.8	1010	840	39.0	38.7		545	.1043	191							162
					RR																		

Computed by [illegible] Date 9-1-7[illegible] Checked by [illegible] Date [illegible]

DEPARTMENT OF ENERGY, MINES AND RESOURCES
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream ROCHER RIVER AT BEN HOULES CABIN for year 19 71

Date	Time	Observer	Water Level	* Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration mgr/1	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration mgr/1	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids mgr/1
JUNE					RR																		
22	1500	BB	6.52	P61	34AB	M	41.2	45.4	1010	560	48.0	47.5	62	547	.1515	277							149
23		BB	6.98	"	35AB	"	77.4	80.0	1085	"	49.6	48.5	64	477	.1893	396							153
24	1343	GE	6.86	"	36AB	"	53.0	52.8	1080	"	49.9	49.0		681	.2015	296	.0085	.0141	.021	7.0	59.0	34.0	167
25	1135	FD	6.68	"	37AB	"	48.2	45.2	1045	"	50.0	49.3		601	.1854	308							149
28	1450	BG	5.35	"	38AB	"	32.0	38.0	1045	"	47.2	46.5	59	485	.3859	796	-	-	-	-	17.0	83.0	170
30	1540	LO	5.73	P61	39AB	M	27.2	28.2	1010	560	48.5	48.0	63	676	.0888	131							147
JULY					RR																		
2	1410	BG	6.29	P61	40AB	M	35.0	35.8	1050	560	49.5	49.0	64	640	.1260	197							164
5	1125	LO	6.50	"	41AB	"	36.6	39.4	1040	"	49.2	48.7	65	584	.1534	263							174
8	0930	BS	6.00	"	42AB	"	39.6	37.8	1040	"	48.5	47.0	61	696	.3235	465							180
9	1505	BS	6.00	"	43AB	"	32.0	32.6	1040	"	49.0	48.0		673	.1832	272	.0020	.0018	3	1.0	29.0	70.0	162
12	1545	BG	5.62	"	44AB	"	30.0	27.0	990	"	47.9	47.5	62	571	.1575	276							170
13	1400	GE	5.80	"	45AB	"	35.5	32.5		"	49.5	48.8		705	.1868	265							172
14	1410	BS	6.35	"	46AB	"	32.2	31.3	1060	"	49.8	49.0		632	.1818	288							170
15	1040	BS	6.95	"	47AB	"	41.0	32.2	"	"	50.3	49.0		723	.2117	293							170
16	1000	GE	7.26	"	48AB	"	39.4	44.4	1060	"	50.6	50.0		607	.1935	319	.0025	.0058	10	3.0	29.0	68.0	165
21	1535	BG	*4.44	"	49AB	"	43.5	41.8	1140	"	50.3	49.8	64	651	.3467	533							177
22	0940	BS	4.20	"	50AB	"	33.2	34.4	1100	"	50.7	50.0		552	.2385	432	-	.0024	4	1.0	17.0	82.0	164
28	1400	BG	3.62	"	51AB	"	27.0	*	1090	"	48.5	48.0		388	.1111	286							173
30	1440	BG	3.36	P61	52AB	M	25.8	24.2	1050	560	48.1	47.5		735	.1266	172							161
					RR																		
			* New gauge					* No sample															
				* DI																			

Computed by [signature] Date 1/12/71 Checked by [signature] Date 14-12-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH – WATER SURVEY OF CANADA

R 267
(9–67)

Suspended Sediment Analysis Results

Stream ROCHER RIVER AT BEN HOULES CABIN for year 19 71

Date AUGUST	Time	Observer	Water Level	Type of Sampler *	Sample Number RR	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
3	1325	GE	3.17	P61	53AB	M	24.1	22.6		560				738	.1181	160							176
6	1215	BG		"	54AB	"	24.1	25.0	1040	"	49.6	49.0		731	.1431	196							167
11	1315	LC	3.64	"	55AB	"	23.2	21.5		560	49.0	48.5		723	.0967	135							150
12	1006	BS	3.56	"	56AB	"	25.2	22.9	1040	900	23.5	23.0		619	.1201	167							154
"	1015	"	"	"	57AB	"	23.0	20.9	"	720	45.4	44.4		651	.1097	159							151
"	1025	"	"	"	58AB	"	22.0	23.8	"	560	48.6	47.6		722	.1452	201							152
"	1035	"	"	"	59AB	"	23.2	23.1	"	400	50.2	49.2		656	.1265	193							188
12	1045	"	3.56	"	60AB	"	24.8	24.8	1040	260	22.7	21.7		561	.1099	196							153
13	1500	"	2.82	"	61A	"	21.0		960	560	48.6	47.5	58	295	*.0436	148							167
13	1505	BS	2.82	"	61B	"		-	960	560	48.6	47.5	58	313	.0430	137							-
17	1135	GE	3.22	"	62AB	"	21.5	19.5		"	49.3	48.6		649	.1173	181							154
18	1010	BS	"	"	63A	"	19.0			"	49.0	48.0	62	411	.1699	413							160
18	1015	BS	3.22	"	63B	"		18.0		"	49.0	48.0	62	275	.0456	166							-
20	1345	GE	3.50	"	64AB	"	16.3	16.0	1020	560	49.2	48.5		665	.0958	144							150
23	1535	BG	2.52	"	65AB	"	24.3	27.6	970	240	15.1	14.5		555	.0556	100							149
"	1550	"	"	"	66AB	"	20.9	22.0	"	400	50.5	50.0		579	.0614	106							143
"	1600	"	"	"	67AB	"	19.3	18.4	"	560	48.4	48.0		662	.0855	129							134
"	1610	"	"	"	68A	"	17.8		"	720	44.7	44.2		395	.0423	107							131
"	1615	"	"	"	68B	"		18.6	"	720	44.7	44.2		*457	.0505	111							-
23	1620	BG	2.52	"	69AB	"	20.2	22.4	"	880	28.4	28.0		630	.0750	119							128
24	0940	BS	2.28	"	70AB	"	18.1	15.2	"	560	48.5	48.0		614	.0674	110							138
25	1500	SH	2.61	"	71AB	"	20.0	20.0	"	"	47.8	47.8	63	670	.0736	110							135
26	1130	SM	2.38	"	72AB	"	16.2	18.3	"	"	48.9	48.4	61	661	.0742	112							135
27	1030	JM	2.60	P61	73AB	M	24.6	25.0	970	560	48.4	48.4		670	.2752	411							134
					RR																		
															* Organic material								
				*DI																			
														* Too full									

Computed by [signature] Date 3/1/72 Checked by [signature] Date 12-12-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 287
(9–67)

Suspended Sediment Analysis Results

Stream ROCHER RIVER AT BEN HOULES CABIN for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °F	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
SEPTEMBER					RR																		
1	1100	DW		P61	74AB	M				560				651	.0610	94							113
8	1530	SF	1.35	"	75AB	M	18.6	20.0		"	46.8	46.4	58	531	1.4697	2768	.0318	.5731	108	39.0	51.0	10.0	120
15	1425	"	2.25	"	76AB	M	21.2	19.8		"	47.5	47.1	57	767	.1019	133							80
28	1410	"	0.40	"	77A	L	31.2		900	"	45.8	45.6	42	329	.0415	126							92
28		SF	0.40	P61	77B	L		30.0	900	560	45.8	45.6	42	332	*.1071	323							–
					RR78 to RR84 Bed material																		

* coarse material

Computed by [illegible] Date 29/1_/71 Checked by C.K.K. Date 22/12/71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 267
(9–67)

Suspended Sediment Analysis Results

Stream SLAVE RIVER AT FORT SMITH for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D50 (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
AUG.					SF																		
4	1315	AW			1									362	.1321	365							180
5	"	DD			2									288	.0752	261							178
6	"	"			3									278	.0775	279							172
7	"	"			4									384	.0910	237							182
8	"	"			5									264	.1006	381							169
9	"	"			6									352	.0766	218							165
10	"	"			7									351	.0989	282							177
11	"	"			8									342	.1004	294							177
12	"	"			9									364	.0789	217							165
13	"	"			10									319	.0676	212							175
14	"	"			11									366	.0649	177							171
15	"	"			12									363	.0651	179							165
16	"	"			13									343	.0691	201							179
17	"	"			14									345	.0931	270							164
18	"	"			15									374	.0863	231							161
19	1315	"			16									332	.0648	195							162
20	1345	"			17									318	.1165	366							161
21	1310	"			18									343	.0978	285							153
22	1410	"			19									332	.1108	334							178
23	1345	DD			20									341	.0497	146							168

Computed by KD Date 30-9-71 Checked by JP Date 19-11-71

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

R 207
(9–67)

Suspended Sediment Analysis Results

Stream SLAVE RIVER AT FORT SMITH for year 19 71

Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
AUGUST					SF																		
24	1315	DD			21									277	.0863	312							160
SEPTEMBER					SF																		
2	1315	DD			22									337	.0338	100							141
3	"	"			23					*				365	.0768	210							158
4	"	"			24					*				310	.0613	198							155
5	"	"			25					*				312	.0634	203							153
6	"	"			26					*				320	.0607	190							161
7	"	"			27					*				346	.0520	150							151
8	"	"			28					*				329	.0375	114							138
9	"	"			29					*				353	.0387	110							141
10	"	"			30					*				338	.0374	111							138
11	"	"			31					*				312	.0450	144							143
12	"	"			32					*				332	.0472	142							142
13	"	"			33					*				299	.0429	143							139
20	1315	"			34					*				321	.0477	149							125
21		"			35					*				352	.0688	195							126
22		"			36					*				389	.0638	164							127
23	1315	"			37					*				267	.0443	166							128
24		"			38					*				323	.0449	139							133
25		"			39					*				353	.0721	204							151
26		"			40					*				334	.0668	200							135
27		"			41					*				337	.0583	173							147
28		"			42					*				398	.0717	180							151
29		"			43					*				359	.0609	170							143
30		DD			44 SF					*				324	.0396	122							150

* Water intake at Fort Smith

Computed by [signature] Date 6/12/71 Checked by C R K Date 23/12/71

R 887
(9–67)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS BRANCH–WATER SURVEY OF CANADA

Suspended Sediment Analysis Results

Stream SLAVE RIVER AT FORT SMITH for year 19 71

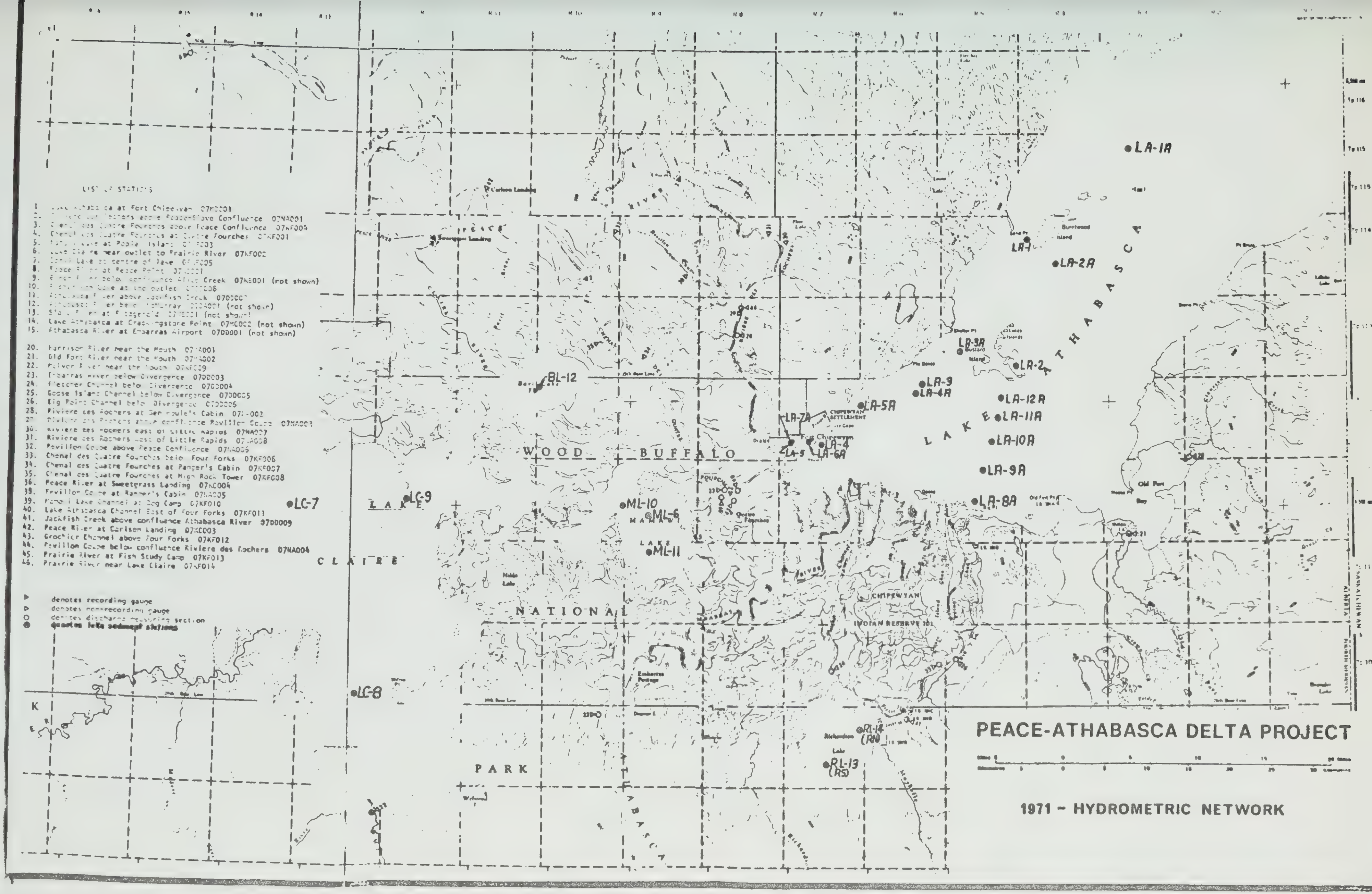
Date	Time	Observer	Water Level	Type of Sampler	Sample Number	Nozzle Diameter	Intake Time A	Intake Time B	River Width	Sample Location	River Depth	Sample Depth	Temperature °C	Volume Sample (c.c.)	Total Sample Dry Weight (gr)	Total Concentration (mgr/l)	Total Sample D_{50} (mm)	Sand Dry Weight (gr)	Sand Concentration (mgr/l)	% Sand .05 to 4.7mm	% Silt .005 to .05mm	% Clay .005mm	Dissolved Solids (mgr/l)
OCTOBER					SF																		
1		DD			45									346	.0378	109							130
2		"			46									343	.0373	109							129
3		"			47									348	.0380	109							119
4		"			48									368	.0400	109							124
5		"			49									389	.0092	24							141
6		"			50									354	.9371	105							126
7		"			51									338	.0370	110							127
8		"			52									335	.0375	112							118
9		"			53									315	.0357	113							121
10		"			54									377	.0425	113							115
11		"			55									328	.0388	118							113
12		"			56									338	.0814	241							123
13		"			57									327	.0353	108							117
14		"			58									281	.0346	123							138
15		"			59									276	.0366	133							135
17		"			60									306	.0406	133							132
18		"			61									356	.0538	151							152
19		"			62									334	.0869	260							136
20		"			63									337	.0379	112							142
21		DD			64									291	.0310	107							155
					SF																		

Computed by [illegible] Date [illegible] Checked by [illegible] Date Jan 14/72

REFERENCES

Guy, H.P., and Norman, V.W.; "Field Methods for Measurement of Fluvial Sediment", United States Department of the Interior, Book 3, Chapter C2, Page 5-15, 1970.

"Measurement and Analysis of Sediment Loads in Streams", Subcommittee on Sediment, Inter-Agency Committee on Water Resources, Report No. 14, Pages 59, 62, 64, 70 and 104, 1963.



PEACE-ATHABASCA DELTA PROJECT
1971 - HYDROMETRIC NETWORK
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
WOOD BUFFALO NATIONAL PARK
PEACE RIVER
ATHABASCA
CHIPEWYAN INDIAN RESERVE 201
CHIPEWYAN SETTLEMENT
Fort Chipewyan
Carlson Landing
Sweetgrass Landing
Burntwood Island
Bustard Island
Old Fort Bay
Embarras Portage
Quatre Fourches
Hilda Lake
Richardson Lake
LA-1A
LA-1
LA-2A
LA-2
LA-3A
LA-3
LA-4A
LA-4
LA-5A
LA-5
LA-6A
LA-7A
LA-8A
LA-9A
LA-10A
LA-11A
LA-12A
BL-12
LC-7
LC-8
LC-9
ML-6
ML-10
ML-11
RL-13 (RS)
RL-14 (RN)
LIST OF STATIONS
1. Lake Athabasca at Fort Chipewyan 07MD001
2. Riviere des Rochers above Peace-Slave Confluence 07NA001
3. Chenal des Quatre Fourches above Peace Confluence 07KF004
4. Chenal des Quatre Fourches at Quatre Fourches 07KF001
5. Lake at Poplar Island
6. Lake Claire near outlet to Prairie River 07KF002
7. Lake at centre of lake
8. Peace River at Peace Point
9. River below confluence Creek 07KE001 (not shown)
10. Lake at the outlet
11. Athabasca River above Jackfish Creek
12. Athabasca River below McMurray (not shown)
13. Slave River at Fitzgerald (not shown)
14. Lake Athabasca at Crackingstone Point (not shown)
15. Athabasca River at Embarras Airport 07DD001 (not shown)
20. Harrison River near the Mouth
21. Old Fort River near the Mouth
22. River near the Mouth
23. Embarras River below Divergence 07DD003
24. Fletcher Channel below Divergence 07DD004
25. Goose Island Channel below Divergence 07DD005
26. Big Point Channel below Divergence 07DD006
28. Riviere des Rochers at Cabin
30. Riviere des Rochers east of Little Rapids 07NA007
31. Riviere des Rochers west of Little Rapids
32. Revillon Coupe above Peace Confluence
33. Chenal des Quatre Fourches below Four Forks 07KF006
34. Chenal des Quatre Fourches at Ranger's Cabin 07KF007
35. Chenal des Quatre Fourches at High Rock Tower 07KF008
36. Peace River at Sweetgrass Landing 07KC004
38. Revillon Coupe at Ranger's Cabin 07NA005
39. Lake Channel at Dog Camp 07KF010
40. Lake Athabasca Channel East of Four Forks 07KF011
41. Jackfish Creek above confluence Athabasca River 07DD009
42. Peace River at Carlson Landing 07KC003
43. Grochier Channel above Four Forks 07KF012
44. Revillon Coupe below confluence Riviere des Rochers 07NA004
45. Prairie River at Fish Study Camp 07KF013
46. Prairie River near Lake Claire 07KF014
denotes recording gauge
denotes nonrecording gauge
denotes discharge measuring section

SECTION J

SECTION J

GROUNDWATER INVESTIGATION, PEACE-ATHABASCA DELTA

by

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INTRODUCTION

Inherent to a thorough hydrological investigation of a basin is the evaluation of its underground water regime. Groundwater is largely hidden from view, and principles of its physical and chemical behaviour are only beginning to be understood. Yet quantitatively, the volume of groundwater in the earth's crust is far greater than that of all fresh surface water. It is estimated that 0.63 percent of the earth's water is underground, while only 0.02 percent is in lakes and streams at any given time (Brown, 1967, p.7). Most of the balance is in the oceans and is not potable.

The presence and movement of groundwater can be interpreted by specialists so as to recognize its effect on soil profiles and fertility, base flow of streams, and distribution of certain vegetation types. Because of the importance of such factors, the Delta Project decided to conduct an investigation into the groundwater regime of the Delta, in order to determine:

1. Whether fluctuations in surface water stage are related to corresponding fluctuations of the water table.
2. Whether artificially raising of levels in the major lakes (ie. Lake Athabasca, Lake Claire, Mamawi Lake) and rivers would also raise levels of smaller adjacent lakes through groundwater transfer.
3. The relationship between plant communities and water table depth in the Delta, and changes in plant distribution caused by changes in groundwater depth.

In order to implement this study, 21 shallow water table wells were installed in seven strategic profiles. In addition, information from ten other wells was made available by Canadian Wildlife Service. All were ten feet or less

in depth, and all were constructed of four-inch diameter slotted plastic pipe. The profiles were assigned letters A to G for identification purposes, except the one installed by Canadian Wildlife Service, which was labelled Transect 4. Elevations of the wells were surveyed, and water levels measured from early August until freeze-up in late October, 1971. Water temperatures were measured twice in 17 wells; and water samples taken from selected wells for analysis.

In addition, six deep test-holes were drilled near Lake Claire to explore for a suspected preglacial valley, as its presence might have a profound influence on groundwater regime of the Delta. These letter holes are numbered H-1 to H-6. All wells and test-holes are located on Figure 1.

ACKNOWLEDGEMENTS

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PREVIOUS INVESTIGATIONS

The bedrock geology of the western edges of the Canadian Shield and of the adjacent Devonian carbonate sequence have been the subject of many investigations starting with those of Macoun in 1877. Such studies are continuing today particularly at the Research Council of Alberta, in order to decipher the complex Devonian stratigraphy of the area. Although no previous groundwater research has been done within the Delta, R. Green, Research Council of Alberta, has noted hydrogeological phenomena such as karst topography and saline springs in adjacent areas.

Bayrock and Root (1972), Research Council of Alberta, have mapped surficial geology and interpreted the Quaternary history of the Delta area. Novakowski (1967) installed five water table wells at various locations, but only one reading was taken at each site.

HYDROGEOLOGY

Bedrock Formations

Precambrian plutonic rocks. These rocks of the Canadian Shield are exposed in numerous small hills in the northeast part of the Delta. The relief of the Shield in adjacent areas is in the order of two hundred feet. Thus it seems probable that similar relief is also present within the eastern part of the Delta (Bayrock, and Root, 1972). Except for some permeability along fault or breccia zones, these rocks can be considered as a virtually impermeable base for all groundwater movement.

Athabasca Formation

The Athabasca Formation, of Precambrian age, does not outcrop, but is suspected to underlie at least part of the Chipewyan Indian Reserve. It consists of white, grey and red medium to coarse-grained sandstone, flat-lying to strongly crossbedded (Green, 1970). Permeability is highly variable, as some areas are tightly cemented, whereas others are completely uncemented.

This formation is buried below an estimated one hundred to two hundred feet of deltaic sediments, and thus probably takes little active part in groundwater movement of the Delta itself.

Devonian Formations

The Devonian sequence of this area consists mainly of sedimentary carbonates and evaporites. Outcrops in the Peace Point area to the west, and south of the Birch River Delta are mainly gypsum. The author also examined a previously unreported gypsum outcrop at Spruce Point. Limestone is abundant in drift of the same area. Green (1970) has mapped many karst features to the north and south of the Delta area. Saline springs, rivers and flowing wells are well-known for several hundred miles both north and south of the Delta. Thus, Devonian groundwater may be expected to be highly saline and, by inference from adjacent areas, may discharge in sizeable volumes. Evidence will be shown later of its influence in the study area.

Surficial Deposits

Pre-glacial alluvium. Virtually no information was available on subsurface hydrogeology of the Delta previous to this investigation, except that which could be inferred from surface features. It was known, however, that several

pre-glacial alluvial valleys were present somewhere in the area, based on studies in adjacent regions. Because pre-glacial alluvial aquifers typically are highly permeable, their depth and distribution were considered important to groundwater regime in the Delta. Therefore, a deep drilling program was undertaken to verify this information, and six deep test-holes were drilled near Lake Claire in March, 1972. They are numbered H-1 to H-6. Results of the drilling program, supplemented by interpretation of geologic and topographic maps, have shown that pre-glacial alluvium occupies channels whose distribution is approximately as shown in Figure 1. Table 1 lists the logs of the six test-holes and one other hole drilled in 1958. The test-hole program revealed that these sediments are of limited importance to surface groundwater behaviour because they are buried below 89 to 240 feet of glacio-lacustrine sediments. Permafrost is also present in some areas. Moreover, glaciation has overdeepened the channels and removed alluvium locally (Bayrock and Root, 1972).

Till

Thin till was present in test-holes H-1, H-3 and H-4. It was reddish in color, sandy, and contained numerous gypsum pebbles, with lesser quantities of limestone and gneissic pebbles. The till is likely of intermediate permeability between that of the pre-glacial alluvium and the overlying glacio-lacustrine sediments.

Table 1

Deep test-hole logs, Peace-Athabasca Delta
(Abbreviations used are standard geological symbols)

H-1; SE-6-113-14- W.4. Elev. 686 ft. March 12, 1972

0 - 16	clay, lt brn-gy, sl calc, sft, slty	
16 - 32	clay, lt brn-gy, sl calc, v sft, slty	
32 - 56	clay, lt gy, calc, v sft, slty	
56 - 88	clay, lt gy, calc, sft, slty	
88 - 140	clay, lt gy, sl mica (or selenite?), v sft, calc, sdy	
140 - 141	sand	
141 - 145	clay, lt gy, v sft, calc, sl sdy	
145 - 145.5	till, granite bldr	
145.5- 156	till, red, sdy, wht gypsum pbls	
156 - 170	sand, qtz, rd-sb rd, v f, poor stg, red clay, pbls, sl calc	

Installed 2" diameter observation well at 159 ft., with pressure gauge at top. Flowing.

H-2; SE-4-112-15- W.4. Elev. 686 ft. March 13, 1972

0 - 6	muskeg, blk, sft
6 - 16	clay, lt gy-brn, firm, calc, slty
24 - 32	clay, dk gy-brn, firm, calc, slty
32 - 40	clay, lt gy, v sft, slty
40 - 43?	sand, s & p, v f, slty, calc, mica
43 - 89	clay, lt gy, v sft, calc, slty, few pink ptgs
89 - 90	sand, grav, pink clay, sd is clear qtz, f-m, sb ang; pbls are gyps, wht; cht, blk; ls, brn. permafrost at 89, $-5^{\circ}C$.

H-3; SE-4-111-15- W.4. Elev. 686 ft. March 14, 1972

0 - 8	clay, sdy, m gy, sft, calc, slty	-
8 - 16	clay, lt brn-gy, sft, calc, slty	$4.0^{\circ}C$
16 - 64	clay, lt gy, v sft, sl calc, slty	3.3° - 4.6°
64 - 80	clay, lt gy, sft, sl calc, slty	3.5° - 4.0°
80 - 88	clay, lt gy, v sft, sl calc, slty	3.5°
88 - 96	clay, lt gy-brn, v sft, sl calc, slty	4.0°
96 - 105	clay, gy, sl sdy, sft, calc, slty	4.1°
105 - 112	till, red, v sdy, m-c, ang-sb ang, clear gyps pbls	4.0°
112	gypsum, bedded, wht-clear, c xtalline	-

H-4; NE-7-110-14- W.4. Elev. 686 ft. March 14, 1972

0 - 8	till, gyps, ls, gran cobbles
8 - 11	gypsum, wht, sft, weathered, bedded
11	gypsum, lt bf, bedded

.... Continued

Table 1 (Continued)

H-5; SW-26-114-12- W.4. Elev. 705 ft. March 15, 1972

0	- 8	sand, wood frag	-
8	- 16	sand, silt, v f, s & p	-1.0°C
16	- 24	sand, f-m, s & p, ang-sb ang, clear - yel qtz	-1.5°
24	- 32	sand, m-vc, s & p, ang-sb ang, clear - yel qtz	-1.0°
32	- 40	sand, m-vc, s & p, ang-sb ang, clear - yel qtz, few ls frag	-0.5°
40	- 47	sand, as above, dark organic debris	-1.0°
48	- 54	sand, m-c, s & p, ang-sb ang, clear - yel qtz, sl calc., end of permafrost	-1.0°
54	- 76	sand, c-vc, s & p, ang-sb ang, clear - lt yel qtz, sl calc	+1.5-9.8°
76	- 112	clay, lt gy, sticky, sft, sl calc, slty	0.5-0.7°
112	- 128	clay, lt gy, sticky, sft, sl calc, slty, pink ptgs	0.9°
128	- 152	clay, m gy, sticky, v sft, slty	0.9-1.6°
152	- 200	clay, lt pink-gy, sticky, sft, sl calc, slty	1.5-1.6°
208	- 232	clay, m pink-gy, sticky, sft, sdy	-
232	- 240	clay, m gy, sticky, harder, sdy	-
240	- 243	pea grav & sd, gneissic, purple qtz, wht qtzite, brn ls.	-
243		bedrock? too hard to collect smpl.	

H-6; SW-28-113-13- W.4. Elev. 690 ft. March 16, 1972

0	- 6	muskeg, blk, sft	-
6	- 8	silt, dk gy, sticky, sft, sl org	+3.0°C
8	- 16	silt, lt gy, sl sdy, sft, sticky, sl calc	3.9°
16	- 24	silt, buff, rusty stks, sticky, sft, calc	3.4°
24	- 56	clay, lt gy, sticky, v sft, sl calc	3.3-3.4°
56	- 80	clay, lt gy, sticky, v sft, sl calc, pink ptgs	3.2-3.5°
80	- 96	clay, lt gy, sticky, v sft, sl calc	3.8°
96	- 120	clay, lt gy, sticky, sft, calc, slty	3.7-3.9°
120	- 200	clay, lt gy, sticky, sft, calc, slty, pink ptgs	3.5-4.6°
200	- 227	clay, m gy, sdy, sft, calc, pink ptgs	4.6-4.9°
227	- 232	clay stones, brick red, abnd frag gyps, v hd	4.8°

Test-hole, NW-29-113-12- W.4. Elev. 690 ft. July, 1958

0	- 25	fine sand
25	- 391	soft silty clay
391	- 392	granite boulders
392	- 394	red clay
394	- 400	soft clay (shale?)

Glacio-lacustrine Sediments

The March, 1972 drilling program showed that the bulk of post-bedrock deposition in the Delta consists of very fine glacio-lacustrine sediments, presumably deposited during and immediately after glacial retreat from the area. These sediments are up to 300 feet or more thick. Analysis of samples from test-hole H-6 show (Table 2) that these deposits are almost entirely in the silt-clay size range. Todd (1959, p. 53) places their permeability (Ks in the range of 10^{-1} to 10^{-3} gal./day/ft.^{2}.

Deltaic Sediments

Deltaic deposits represent a relatively thin veneer above the glacio-lacustrine materials in most of the Delta. West and immediately north of Lake Claire, such deposits are predominantly sandy and are about 10 to 25 feet thick. At Sweetgrass Landing, however, the 1972 drilling showed a thickness of 76 feet. In this area, deltaic sand is coarse to very coarse at the base, decreasing to very fine and silty at the present land surface. Mechanical analyses of samples from test-hole H-6 (Table 2) indicate that the deeper sediments were deposited in quiet conditions. More turbulent conditions prevailed during deposition of the top 120 feet of sediment, as evidenced by lower clay and higher sand content.

Modern and recent deposition in the Athabasca part of the Delta consists of somewhat finer material (Table 3), as shown from mechanical analyses of the E and F profile samples. Permeabilities (Ks) in this material are in the order of 10^{-1} to 10 (Todd, 1959, p. 53).

Table 2

Mechanical Analyses of Samples, Test-hole H-6

Depth (ft.)	Sand (%)	Silt (%)	Clay (%)
24	6	45	49
40	8	62	30
64	3	49	48
80	2	73	25
104	2	58	40
120	4	65	31
136	0	45	55
168	0	45	55
184	0	24	76
192	0	4	96
216	5	34	61

Table 3

Mechanical Analyses of Samples, Profiles E & F

Depth (ft.)	E-1 Sand (%)	E-1 Silt (%)	E-1 Clay (%)	E-2 Sand (%)	E-2 Silt (%)	E-2 Clay (%)	E-3 Sand (%)	E-3 Silt (%)	E-3 Clay (%)
2	20	68	12	5	77	18	3	74	23
4	13	70	17	19	66	15	3	66	31
6	8	71	21	7	73	20	3	63	34
8	7	71	22	3	74	23	5	75	20
10	5	69	26	5	71	24	3	74	23

Depth (ft.)	F-1 Sand (%)	F-1 Silt (%)	F-1 Clay (%)	F-2 Sand (%)	F-2 Silt (%)	F-2 Clay (%)
2	10	73	17	6	65	29
4	8	71	21	0	57	43
6	8	68	24	4	54	42
8	4	69	27	9	63	28
10	6	72	22	41	35	24

GROUNDWATER REGIME

Permafrost

The Peace-Athabasca Delta is climatically within the zone of discontinuous permafrost, as defined by R.J.E. Brown (1967). Brown defines permafrost as "the thermal condition of earth materials such as soil and rock when their temperature remains below 32°F continuously for a number of years." Its presence has been verified for the first time at several locations in the Delta. In September, 1971, permafrost was encountered in test-hole G-3 at 3.5 feet. This occurrence may be continuous with permafrost from 10 to 54 feet discovered at Sweetgrass Landing (test-hole H-5) in the March, 1972 drilling program. In test-hole H-5, frozen ground was at a temperature of -1°C. Operators of the sawmill at Sweetgrass have reported the presence of permafrost for several miles along the banks of the Peace River.

Test-hole H-2 encountered permafrost at 89 feet, where the temperature was -5°C. Hard drilling in H-1 at 170 feet may also have been permafrost, but this remains unverified. Dr. H. Dirschl, Canadian Wildlife Service (pers. comm.) encountered frost lenses in August, 1971, while drilling observation wells in Transect 4. These may also have been permanently frozen.

Conditions favoring permafrost include a heavy vegetative cover to insulate the ground from solar radiation. This is the case in Transect 4 and was so at Sweetgrass Landing until about 1958, when logging operations began. A northerly aspect at Sweetgrass would also favor permafrost presence.

Permafrost at depth in hole H-2 and suspected in H-1 is not in equilibrium with the present climate, but is a relic from Pleistocene time. Pre-glacial

alluvium at the base of test-hole H-5 was not frozen. However, the water contained therein was saline and could have been below 32°F. Its presence in sand and gravel at the several sites investigated suggest that it might be widespread in coarse materials elsewhere in the Delta. None was observed in the glacio-lacustrine silty clay zones however.

Nature of Flow Systems

The distribution of flow systems is determined partly by the topography of the water table, which creates the head, or driving force, to move groundwater. It is modified by the geology, which tends to concentrate flow lines along more permeable strata. Climate and geology jointly determine the volumes of water available to be involved in groundwater movement.

In humid regions such as this, the water table is a close approximation of surface topography. Thus, except where modified by geology, groundwater moves normal to the contour from topographically high to low areas.

Regional groundwater systems in this region recharge in the Caribou Mountains to the northwest and in the Birch Mountains southwest of the Delta. Groundwater moves radially down-gradient from these two highs, having a head of at least 2,000 feet. The discharge end of these systems is at Lake Claire and the lower Peace River. Despite the size and head of these two major regional systems, the quantity of groundwater involved is small. Practically the entire geologic section from the bed of the Peace River to the top of the two major highs consists of soft marine shale having an extremely low permeability. The bulk of regional groundwater discharge is into the preglacial Shaftsbury Valley (Tokarsky, 1966). That this valley is indeed a discharge feature in

the Delta area is confirmed by an observation well installed at H-1. The well was bottomed in preglacial sand at 159 feet. A pressure gauge installed at the top of the casing showed a head of 16 feet above ground level. The Embarras and Chipewyan Valleys may also be discharge features, but this has not been verified.

Potentially widespread relic permafrost conditions and glacial removal of buried channel alluvium would somewhat restrict the effect of regional flow systems on the Delta. In any case, up to 200 to 300 feet of impermeable glacio-lacustrine silty clay covers such alluvium and thus regional flow systems are of limited consequence to local groundwater regime at the land surface.

Maximum relief in the Delta itself is in the order of ten feet. Therefore, no intermediate flow systems exist, but a vast number of local systems are present.

Twenty-seven water table wells were installed in seven profiles late in July, 1971 to study local groundwater regime of representative sites. Three profiles were chosen at and adjacent to Mamawi Lake to evaluate the amount of subsurface flow between large and small lakes when relative water levels are altered. Three more were installed across levees from modern channels to backswamp lakes to evaluate groundwater transfer when levels change in such channels. Transect 4 south of Mamawi Lake was installed by Canadian Wildlife Service for their studies. Water levels were read in all the wells and adjacent channels and lakes from early August, 1971 until freeze-up.

Another four wells (Profile G) were drilled in September, 1971 between Lake Claire and Peace River, to determine whether subsurface flow occurs between them.

Figure 2 shows two groundwater profiles, representative of Profiles A, B and C, and of Profiles D, E, and F. Water table configuration at times of shallowest and deepest groundwater depth have been plotted. The water table in Profile A is lower everywhere than surface water, but only six feet below ground level at the lowest point. Were it not for consumptive use by vegetation, this profile would be a groundwater "mound" rather than a depression. Its configuration is a result of water removal by willows exceeding infiltration from rainfall.

Six sets of water level readings were taken in Profiles A, B, and C. In all but one set of readings, the water table was lower everywhere than the surface water level at both ends of the profile. The one exception was in Profile C on August 4, 1971, when the water table formed a gradient from "P" Lake down to "S" Lake, a drop of 1.7 feet. Therefore, no subsurface transfer of water takes place from one lake to another in this area, despite differences of several feet in head between lakes.

Profiles D, E, and F were more variable. The early readings, in August, 1971 indicated a groundwater mound under the highest part of each levee. In September and October, surface levels in the channels dropped, precipitation was low, and a water table gradient formed from the lake toward the channel in all three cases. Difference in head gradually increased to slightly over four feet. In Profile E, the water table actually rose slightly between well

E-2 and Frezie Lake, due to cessation of consumptive use at the end of the growing season.

The August readings suggest that groundwater flow at that time was primarily a matter of vertical downward percolation. The depth to water was a function both of infiltration rate, and consumption use on the levees. However, by September, consumptive use, lack of rainfall and lack of downward percolation had changed the picture to that of a gradient from lakes behind levees toward the channels, indicating flow in this direction. The amount of this flow may be estimated, using Darcy's equation:

$Q = PIA$, in which

Q = flow, in gallons per day

P = permeability, in gallons per day through one square foot cross-section, under unit hydraulic gradient

I = gradient, in feet per foot

A = cross-sectional area, in square feet.

For each mile length of levee, assuming a 10 foot thickness of levee is involved in groundwater transfer, with an average head difference of 4 feet, and using an approximate K_s for sandy silt, flow through levees would be:

$$Q = (3)\ (4/300)\ (5280 \times 10)$$

$$= 2{,}112 \text{ gallons per day per mile length}$$

Artificially raising levels in the various channels would roughly double the head difference. Using Todd's higher value for permeability (3) and a head difference of 8 feet, artificial works would cause a water transfer of:

$$Q = (3)\ (8/300)\ (5280 \times 20)$$

$$= 8{,}880 \text{ gallons per day per mile length,}$$

$$= 6 \text{ gallons per minute per mile length.}$$

This latter figure is probably the maximum to be expected and shows that subsurface transfer from one water body to another would be negligible.

The configuration of the water table in Profile G and Dirschl's Transect 4 closely follows the land surface and reflects only the inter-action of local infiltration and consumptive use. Permafrost at G-2 and a lack of gradient between Peace River and Lake Claire indicate that no groundwater transfer takes place between them.

Groundwater Level - Vegetation Relationship

Most plants favor very specific environments, which are a combination of climatic, hydrologic and chemical factors. In the Delta, climate and soil chemistry are relatively uniform over large areas. The main variable in determination of plant distribution is thus the local moisture budget, which in turn is related to micro-relief. Plant distribution as of September, 1970 has been interpreted by Canadian Wildlife Service from photographs taken at that time. Figure 3 is a water table map, in which average depth to water table is inferred from the results of the present study and from the interpretation of vegetation distribution. It is based on water table depth variations shown in Table 4. Figure 4 is a diagrammatic profile of water-table relationship to vegetation across a typical levee.

Table 4

Relationship of Vegetation Type to Depth of Water Table

Plant Type	Water Table Depth (ft.)
Open Water	0
Emergent vegetation in water	0
Mudflat	0
Meadow and immature meadow (including marsh species out of water)	0 - 3
Low shrubs	1 - 4
Tall shrubs	3 - 5
Mixed Forest:	
-Deciduous forest	4 - 7
-Coniferous forest	>6
Rock outcrop	-

The limited 1971 investigations have shown two general groundwater conditions within the Delta. The first occurs in older, more compacted areas (Bayrock and Root's number 1 and 2) of the Delta. In these areas, micro-relief and permeability are lower than in the number 3 and 4 areas. Based on three profiles adjacent to Mamawi Lake, the water table in such areas is a depression between water bodies, as typified by Profile A in Figure 2. This configuration held true through three months of observations in the three profiles during 1971.

Some very small inflow of water from Mamawi Lake and "S" Lake takes place toward the lowest part of the profile, in addition to vertical downward percolation of precipitation. Lowering of lake levels and drying up of backswamps such as "S" Lake are causing the water table to drop. Landward percolation of groundwater is minor in comparison to percolation of surface water, because of a much smaller difference in head. Seasonal variations result from the relationship between infiltration rate and consumptive use, and will not change significantly with anticipated changes in surface water levels. However, the water table in the shoreline area between A-1 and Mamawi Lake fluctuates in response to surface water changes, the response diminishing in magnitude with increasing distance from the lake.

Plant distribution in the higher part of this profile will probably remain about the same as at present. However, distribution in the lower areas along Mamawi Lake and backswamp areas will change significantly as lake levels continue to decline. Many of the backswamp areas, formerly shallow lakebeds, have already dried up, and others such as "S" Lake are doing so. As they dry up, the water table drops below the lakebed surface, and zones of emergent

vegetation in open water are replaced by low willow and high willow.

The other general groundwater condition occurs in modern areas of the Delta (Bayrock and Root's number 3 and 4 areas), where sediment compaction is less and permeability is therefore greater. In such areas, recharge in the levees is sufficient that a groundwater "mound" exists, at least seasonally. This is true in Profiles D, E, and F (Figure 2). Thus, groundwater flows from the levee laterally both to the channel on one side and to the backswamp on the other. The shorter flow path and coarser grain size of sediments toward the channel would divert the bulk of groundwater flow in this direction.

Seasonal and long-term drop of water levels in the various channels causes some lowering of the groundwater "mound" immediately adjacent to the channels in a narrow band (as in well E-1, Figure 2). If water levels in such channels remain permanently low, resultant changes in vegetation will be long-term, in that spruce forest may replace poplar forest. Spruce forest, where already established, will remain the climax vegetation. The depth to groundwater behind levees will gradually drop below the land surface as backswamps and lakes disappear. Here again, using Figure 2 as an example, the zone between wells E-2 and E-3 will gradually be invaded by poplar forest, and emergent vegetation in Frezie Lake will in turn become meadow, then low willow/shrub flats.

Recharge Rate

The rate of groundwater recharge within the Delta may be estimated and compared in 1971 with that of the long-term average. Estimates which follow are based upon measurements of water table wells for only 1.5 months in Profiles

A, B and C; and 2.5 months in Profiles D, E, F and Transect 4. As only two sets of measurements were obtained from Profile G, they were not used in estimating annual recharge.

During the 1971 calendar year, subsurface frost conditions were found to be present until late May to early June. The water in observation wells again froze in late October, when the final measurements were made. The period during which no ground frost was present and groundwater recharge could occur was therefore approximately 4.5 months.

Groundwater recharge was considered to have occurred each time a water-table measurement was higher than the previous one in the same well. The total amount of recharge was totalled for each well over the period that measurements were taken, and the values thus obtained were averaged for each of the three main areas where water table wells were installed. An average specific yield of 0.1 was assumed for all profiles. Total recharge is shown in Table 5.

Table 5

Groundwater Recharge Rates,
Peace-Athabasca Delta, 1971

Profile	Average Water Table Increment (ft.)	Time Period (mo.)	Corrected to 4.5 mo. (ft.)	Water Table Increment (in.)	Increment x Specific Yield (in.)
A, B, C	0.36	1.5	1.08	13.0	1.30
D, E, F	1.72	2.5	3.09	37.1	3.71
Transect 4	0.70	2.5	1.26	15.1	1.51
All profiles	0.98	2.5	1.76	21.2	2.12

Thus, average groundwater recharge for all profiles is roughly 13 percent of the annual precipitation of 16.71 inches (as recorded at Fort Chipewyan airport) in 1971.

The interpretation of aerial photography of September, 1970, showed that land area of the Delta was 1,009,013 acres, exclusive of Precambrian outcrops. Assuming that these average groundwater recharge values hold for the entire Delta, total recharge for 1971 was:

$$(1{,}009{,}014)\ (2.12/12) = 176{,}000 \text{ acre-feet.}$$

A comparison of the 1968 and September, 1970 aerial photography shows that 124,320 acres of land were exposed during that time due to lowering of water levels in the Delta. Of this area, 53,843 acres were in mudflats, whose water table is virtually at the land surface. The remaining 70,477 acres is in immature meadow, having an assumed average water table depth of 1.5 feet. Thus the decrement of groundwater storage from 1968 to 1970 is about (1.5) (0.1) (70,477) = 10,570 acre-feet, or six percent of the 1971 recharge. The loss in 1971 would probably be somewhat greater as many lakes continued to dry up and the mudflats turned into willow with correspondingly lower water tables.

Groundwater recharge, as calculated by the above technique admittedly has shortcomings. It ignores for example, the quantities of water lost to consumptive use, and although the specific yield value is considered reasonable, it has no basis in fact. The frequency of well measurement could have missed some increments to the water table also. Nevertheless, this exercise does yeild an order-of-magnitude value for recharge, and allows comparison of recharge rates in parts of the Delta of differing ages. Both Profiles A, B

and C, and Transect 4 are in Bayrock and Root's number 3 area. Profiles D, E and F, having the highest recharge are in the most modern (number 1) area.

Groundwater Quality

Little is known of groundwater chemistry on a regional basis in the Delta, as few analyses are available. However, the deep testing program of March, 1972 yielded samples from three different depths in test-hole H-1 and two samples from test-hole H-5.

Eleven analyses were used from the 1971 investigations from nine water table wells in Profiles A to F. Several of these wells were sampled twice. Temperature was measured at the time of sampling at most sites. All analyses were converted from milligrams per litre (mg/l.) to equivalents per million (epm), and percentages of various ions were computed. Analyses from test-holes H-1 and H-5 were done by the Department of Environment Laboratory, Edmonton, and Research Council of Alberta Laboratory, Edmonton. The analyses are tabulated in Tables 6 and 7.

Table 6

Geochemistry of Deep Groundwater

	H-1, 140'	H-1,159'	H-1,170'	H-5, 56'	H-5, 242'
Date of sampling	Mar 12/72	Mar 13/72	Mar 12/72	Mar 15/72	Mar 15/72
Temp. at sampling (^{o}C)	--	7	--	9.8	--
pH	7.7	6.7	7.1	7.1	6.6
E.C.	2.72	3.36	3.20	1.29	12.00
Ca^{++} (mg/l)	504	700	730	296	1280
Mg^{++}	31	90	30	20	180
Fe (total)	<.05	.20	4.50	.20	.05
Na^{+}	154.1	193	161	20	1587
K^{+}	14.0	10.1	16.0	5.0	17.0
$CO_3^{=}$	--	--	--	--	--
HCO_3^{-}	280	311	201	659	119
$SO_4^{=}$	1521	1781	1646	288	1603
Cl^{-}	202	319	277	18	4129
T.D.S.	2709	3409	3066	1296	8915
S.A.R.	1.7	1.8	1.6	0.3	10.9

Table 7

Geochemistry of Shallow Groundwater
(mg./l.)

Location	Temp. (^oC)	pH	TDS	Ca	Mg	SO_4	Cl	HCO_3	NO_3	Fe	F	Na	K
A-1	5.2	6.9	788	194	32	230	12	379	2.8	.18	.25	21.3	3.3
A-2	3.9	6.9	920	220	89	165	17	853	7.2	.19	.13	38.8	3.8
A-3	10.0	6.9	536	150	27	45	19	435	17	.14	.19	23.8	1.7
B-2	2.8	6.9	640	250	55	21.5	13	872	2.0	.39	0	23.8	5.0
C-2	4.5	6.7	1880	111	105	900	8	540	0	--	--	--	--
	6.7	7.2	1862	400	100	780	12	650	5.0	1.17	.18	47.5	4.2
D-2	5.6	6.8	678	190	42	41.5	25	595	5.6	.65	.16	25	2.5
E-2	2.8	7.4	1150	220	82	200	30	789	7.3	.39	.08	40	3.0
E-3	6.7	7.4	1074	200	62	324	21	412	2.9	.14	.05	40	2.1
F-1	7.8	6.7	542	142	25	32	31	426	16.3	.29	.1	30	2.1
F-2	2.2	--	960	52	52	30	23	650	0	--	--	--	--

In the southern plains, Vanden Berg and Lennox (1969, p. 27-28) found that sodium as a percentage of total cations increases with length of flow path toward the discharge end of the system. This is a result of ion exchange, in which calcium and magnesium are absorbed onto clay platelets, in exchange for sodium ions. The opposite situation appears to exist here, as sodium decreases from 19 percent to 15 percent of total cations with increasing depth. Bedrock formations of the area are highly calcic, being mainly limestone, dolomite, and gypsum. Thus, surficial clays above bedrock might well be saturated or nearly saturated with respect to calcium and magnesium, inhibiting further ion exchange. Deeper flow paths coming into closer contact with bedrock would thus pick up greater concentrations of calcium which cannot be exchanged for sodium.

Calcium to magnesium ratio increases from 4.6 to 5.6 with increasing depth and longer flow path, as Vanden Berg and Lennox (1969, p. 29) suggest in the Hand Hills area.

No clear-cut patterns of flow behaviour can be deciphered from examination of the anion ratios. High sulphates in all three samples (73 to 76 percent) are probably a result, however, of the proximity of gypsum subcrops. All three samples are of the calcium-sodium/chloride-sulphate facies.

In test-hole H-5, the sample from 56 feet depth shows relatively low total dissolved solids (1296 ppm), with calcium as the dominant catio and bicarbonate as the dominant anion, suggesting a relatively local source for this water. In the 242 foot sample, sodium is 47 percent of total cations, and chloride is 77 percent of total anions. Considered with an extremely high total dissolved solids (8915 ppm), a flow path involving Middle Devonian evaporite

rocks (McCrossan and Glaister, 1964, pp. 49-53) is suggested.

Of the 11 analyses available for shallow wells, 10 are of the calcium-magnesium cation facies. Eight are bicarbonate-chloride-sulphate, one is bicarbonate, and two chloride-sulphate-bicarbonate anion facies.

These analyses reflect, in general, the shallow nature and short flow paths followed by the near-surface groundwater. Substantial differences in temperature and thus of solubility in adjacent samples help explain differences in their detailed geochemistry.

Groundwater temperature was measured on August 11, 1971 and again on September 20, 1971 at all sites, except one where the level had dropped too low for a second reading. Highest temperature observed was 10°C, and lowest was 1°C. With two exceptions, groundwater temperature was higher in the September reading, despite much lower air temperatures. Lowest temperatures occurred where the water table was deepest. Groundwater temperature dropped to the freezing point and readings were discontinued in late October. Water temperature, therefore, appears to change as a delayed response to air temperature, and the amount of change is a function of the depth to water table.

SUMMARY AND CONCLUSIONS

The nature of the shallow water table is a major determinant in distribution of plant types in the Delta. Lower levels of surface water and the absence of floods since 1968 are causing the water table to drop in certain areas, notably adjacent to present lake beds and in former lake beds behind the levees. This phenomenon is causing low willow/shrub to invade and replace meadows,

and high willow to invade low willow/shrub in these areas. The highest parts of modern levees have a water table whose depth is determined by permeability of the soils and local recharge from precipitation, rather than by surface water fluctuations. Thus the dominant vegetation, ie, spruce and aspen, will remain unchanged in these areas, as such vegetation prefers a deep water table.

Recharge rate and water table configuration are related to the relative geological age and degree of compaction of the deposits in the several subdeltas. Older, more compacted subdeltas have a lower recharge rate and the water table is lower in the land area between lakes than the level of the lakes themselves. This is a result of consumptive use exceeding groundwater recharge. In modern parts of the Delta, compaction of sediments is less, and relief, permeability, and recharge are greater. Thus the water table forms a mound in the levees, except during periods of low or no recharge.

Although water transfer does take place from lakes to channels through levees during part of the year, the volume of water involved is negligible. No subsurface water transfer occurs between Peace River and Lake Claire.

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LEGEND

Preglacial valleys

H-1 to H-5 Deep test holes

G-2 to G-5 Shallow observation wells

Transect 4 Shallow observation wells and profile

A to F Shallow observation wells and profiles

FIGURE 1 Location of Groundwater Investigations

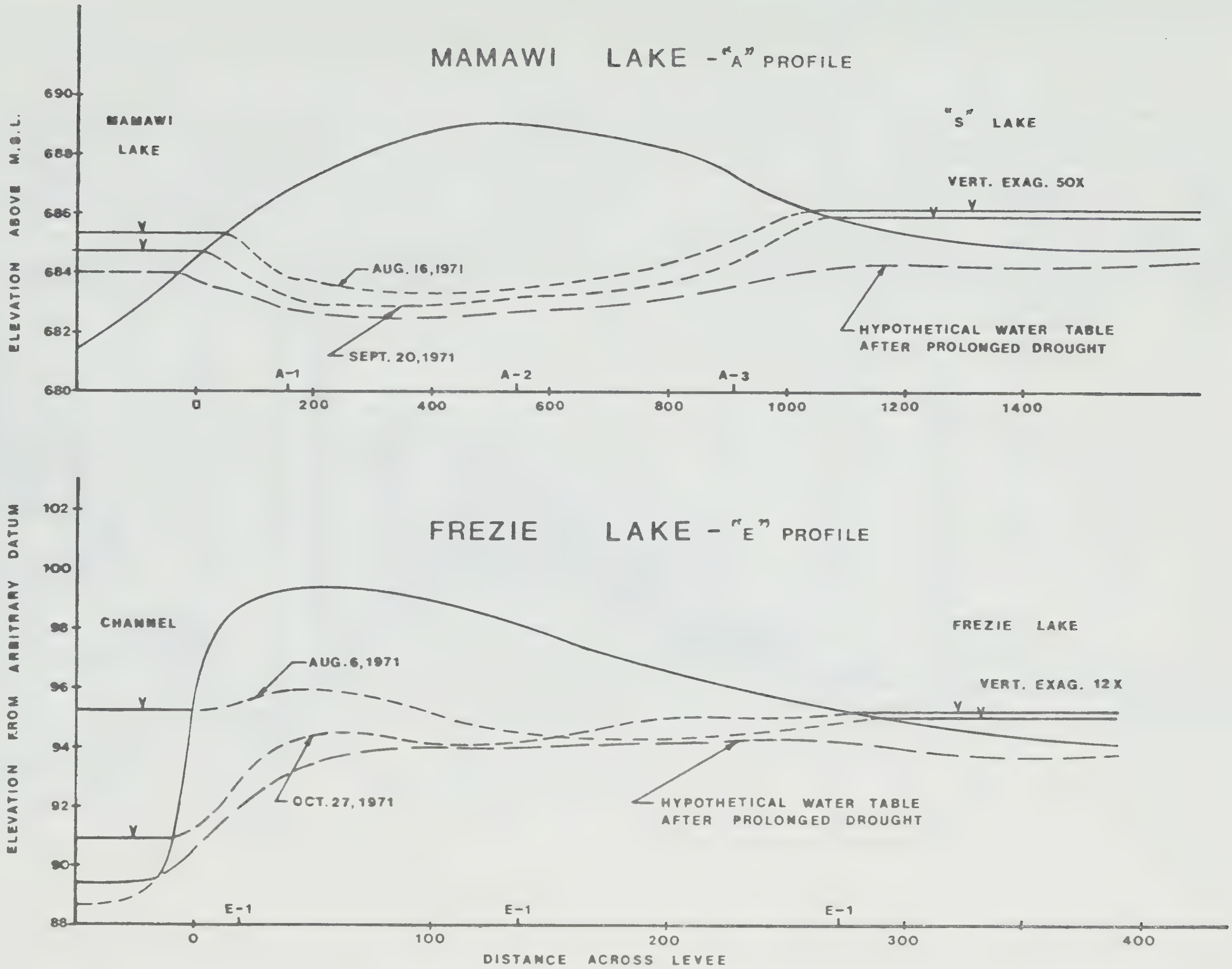

FIGURE 2

GROUNDWATER PROFILES "A" & "E"

		Water Table Depth
1	Open Water	0'
2	Emergent Vegetation in Water	0'
3	Mud Flat	0'
4	Meadow (including marsh species out of water)	0 - 2'
5	Low Shrubs	1 - 4'
6	Tall Shrubs	3 - 5'
7	Deciduous Forest	4 - 7'
8	Coniferous Forest	6 - 7'
9	Rock Outcrop	-
10	Immature Meadow	0 - 3'

Figure 3

Average Water Table Depth

See Vegetation Map - Volume 2, Ecology Appendices

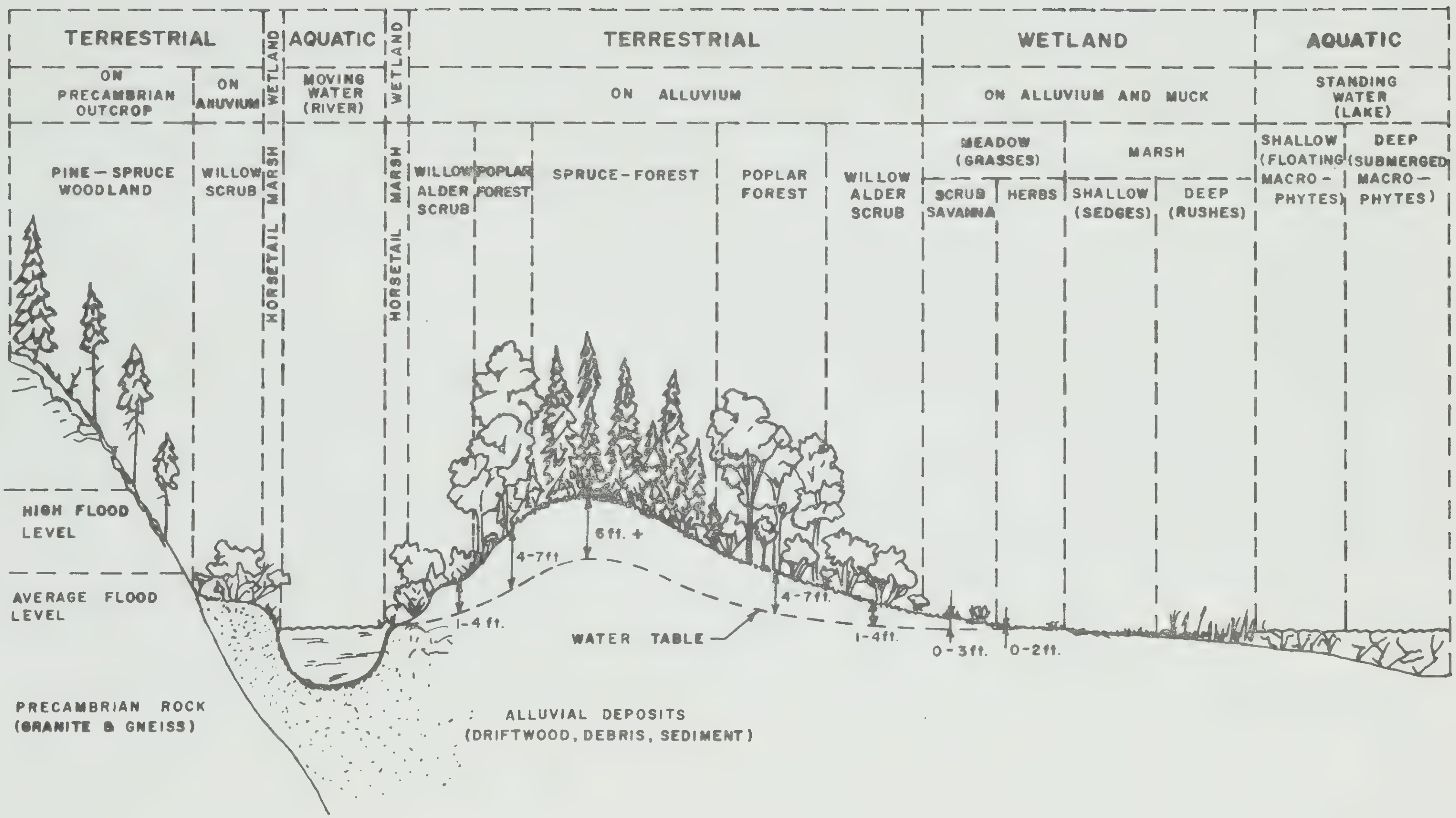

FIGURE 4

DIAGRAMMATIC PROFILE OF WATER-TABLE RELATIONSHIP TO VEGETATION

SECTION K

SECTION K

HYDROMETRIC FIELD INVESTIGATIONS AND SURVEYING

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Edmonton

1972

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HYDROMETRIC INVESTIGATIONS

Description of Network

The hydrometric network used during the study for the Peace-Athabasca Delta Project consisted of 12 recording water level gauges and 22 non-recording water level gauges. In addition to collecting water levels on rivers and lakes, discharge measurements were made at 15 locations throughout the area.

This network was developed using the gauging network of the Water Survey of Canada as a base along with the network used by the Water Resources Division (then Department of Agriculture), Department of the Environment, during 1970. Fig. 1 shows the location of gauges used during the study. Appendix K-1 includes the description and an inventory for each station. This report will deal primarily with those stations established and operated by personnel assigned to the Peace-Athabasca Delta Project.

Water Level Recording Stations

One of the findings of the Athabasca Delta Study Report was the approach necessary to predict flows through the outflow channels from Lake Athabasca, Lake Mamawi and Lake Claire. This approach called for a measure of the elevation difference between the extreme ends of the river channels. With this requirement in mind staff gauges and water level re-

corders were installed to monitor the elevation differences for the major river channels in the Delta, as well to provide water levels at points along each channel.

Discharge Measuring Stations

The procedures and equipment used to measure river discharges were those normally applied by the Water Survey of Canada. Except where wading was permissible all measurements were made from boats. Portable tag lines were used on the Chenal des Quatre Fourches at Four Forks, the Grochier Channel at Four Forks, and the Revillion Coupe. Four the Riviere des Rochers a permanent tag line was installed on the east bank.

Current meters and weights were suspended by type A or type B sounding reels attached to metering boards or boat cranes respectively.

Winter discharge measurements were made from ice cover on the Riviere des Rochers at the winter road crossing indicated in Figure 1.

Snow Surveys

During the months of March and April an attempt was made to estimate the snow accummulation in the Birch River watershed.

Seven snow courses were used in the area representative of the Birch

River watershed and the water equivalent ranged from 3.3 to 4.9 inches. The mean for seven stations is 4.4 inches. Table 1 summarizes the results for the Birch River area.

Table 1 Snow Survey Summary

Date 1972	Snow Course	Depth of Snow	Length of Core	Water Content
March 20	7	22.0	10.0	3.3
March 22	2	24.0	13.0	4.3
	3	26.6	15.1	5.6
	4	22.6	11.3	4.4
April 4	1			3.9
	5	31.2	13.8	4.9
	6	25.5	14.5	4.5

Fig. 2 shows the Snow Course locations.

SUMMARY OF RESULTS

Water Levels

Water level records for recording and non-recording gauges are summarized in Appendix K-1. For non-recording stations each daily value represents an instantaneous reading made on that day. For those non-recording stations at which discharge measurements were made, e.g. Riviere des Rochers at Ben Houle's Cabin 07NA002, the value represents

the mean water level of two readings taken at the start and end of a discharge measurement. The time period involved is one to two hours, depending on the station. For recording stations each daily value represents a weighted mean of the continuous record for that day.

Discharges (Flows)

River flows have been summarized using two approaches:

(1) those stations for which stage-discharge relationships were developed. Daily discharges are presented. This group consists of stations operated by Water Survey of Canada.

(2) those stations for which no stage-discharge relationship may be developed. A summary of each individual discharge measurement is presented with special note being made as to flow direction for those stations subject to reversing flow. Flow data are shown in Appendix K-1.

DISCUSSION OF RESULTS

Water Levels

The general trend of water levels in the Peace-Athabasca Delta is for the low winter levels to recover for a brief period during spring break-up. The levels obtained during this period may be extreme for short periods, depending on the location and duration of ice jams along the Peace or Athabasca Rivers. With open water the water level generally

recedes to a level higher than the low levels experienced over the winter period.

As the flow and elevations of the Peace and Athabasca Rivers gradually increase with snow melt from the uplands of their watersheds, the lakes within the Delta begin their rise to the annual peak. The rise is complemented by local inflow from smaller rivers in the east end of Lake Athabasca, Fond du Lac and McFarlane and from flow into Lake Claire from the Birch and McIvor Rivers. The peaks obtained within the Delta depend primarily upon the respective discharges in the Athabasca and Peace Rivers and the times at which they enter the Delta area. A comparison of the hydrographs for Lake Athabasca, Lake Claire, Mamawi Lake and Quatre Fourches with the discharge Hydrographs for the Peace River at Peace Point and Athabasca River below McMurray (with appropriate allowances for lag time to the Delta area) will demonstrate water level relationship with discharge in the above rivers.

While water levels in Lake Athabasca and adjoining lakes are subject to the controls exerted by the flow in the Athabasca River and the Peace River the local effect of wind has been very clearly demonstrated during the 1971 data collection period. Sudden changes in Lake Athabasca levels at the west end of the lake have been observed with the perdominance of an east or west wind. Lake Athabasca has been observed to rise up to

two feet over a six hour period and fall up to one foot over the same period of time. The effects of the wind are experienced at Quatre Fourches and Mamawi Lake as is demonstrated when water level records for these stations are compared. Water level records for Lake Athabasca at Fort Chipewyan, Chenal des Quatre Fourches at Four Forks, Mamawi Lake at Poplar Island, Lake Claire near outlet to Prairie River are given in Appendix K-1.

Discharge

The most unique aspect of flows in the rivers within the Peace-Athabasca Delta is the reversal of flows. Flow in the Chenal des Quatre Fourches and the Riviers des Rochers is controlled by the relative elevations of the Peace River and Lake Athabasca, while flow in the Revillon Coupe is controlled between the relative elevations of the Riviere des Rochers (at its confluence with the Revillon Coupe) and the Peace River. The Mamawi Channel flow is controlled by the relative elevation of Quatre Fourches and Mamawi Lake and Lake Claire.

While the effect of wind may indirectly affect the flow (quantity) in the Chenal des Quatre Fourches and the Riviere des Rochers, the Mamawi Channel and Prairie River are very sensitive to the effects of wind, primarily because of the smaller volume of water carried. Mamawi Channel flow has been observed on more than one occasion to be moving in two directions.

Vertical Control

We have shown where the flow pattern in the Delta is influenced by the sometimes delicate balance of water levels. As a result, vertical control has played an extremely important part in establishing and operating this hydrometric network.

During the 1970 study by Water Resources Division, the existing bench mark network of GSC was extended to accommodate the location of water level gauges (see Fig. 7 Athabasca Delta Project Report #1). A more detailed and extensive exercise of establishing bench marks was undertaken by the Peace-Athabasca Delta Project in the late winter and early spring of 1971 as a prelude to the data collection program of the 1971 open water season. This network is shown in Figure 3. During the course of collecting field data, numerous checks were made to ensure as high a degree of control as possible.

Other Surveys

During the course of field investigations several other surveys were carried out to clarify certain hydrologic conditions. The channels of Baril River and Claire River were surveyed to provide a longitudinal profile of each channel and cross-sections of the channels at 5000 foot intervals. There surveys indicated that the Baril River was still an active channel and permitted a theoretical calculation of its discharge

capacity. The Claire River was found to be effectively closed at the Peace River end of the channel and in its present state it carries water toward Lake Claire only if the Peace River overtops its banks at Sweetgrass Landing.

To the south east of Lake Claire a similar survey was carried out on a stream known locally as Gull River. This river appeared to be a potential channel for movement of water from the Embarras River into Lake Claire. The survey showed that there was no direct connection of Gull River with the Embarras River and therefore no flow in its present condition. The Gull River does however extend right to Lake Claire. The survey revealed that Gull River was very deep in some sections and could possibly have been a major distributory of the Athabasca River delta at some time in the past.

In conjunction with the construction of the Quatre Fourches Impoundment, a survey was made to determine if there were other outlets to Mamawi Lake which would perhaps enlarge and decrease the effectiveness of the impoundment. This survey concentrated on the small channels which connect the east side of Mamawi Lake to Grochier Channel which joins Chenal des Quatre Fourches. The survey indicated that these small channels would not carry water until the level of Mamawi Lake exceeded elevation 688.5.

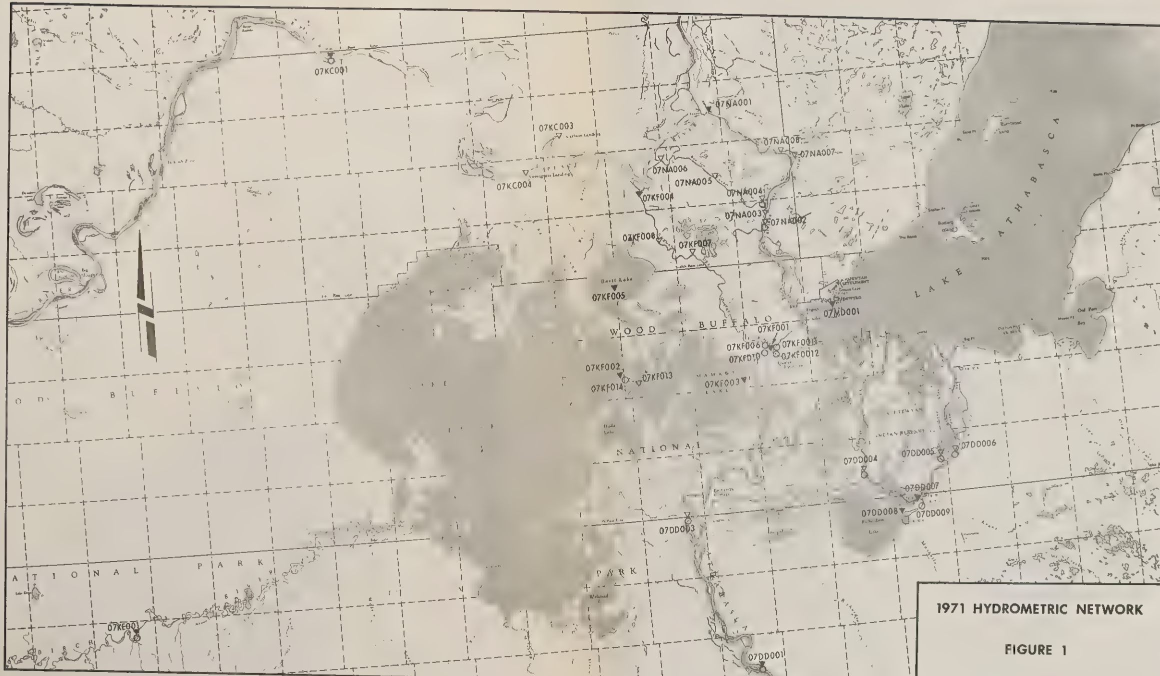
These surveys and other surveys related to ecological investigations are shown on Figure 4.

F I G U R E S

HYDROMETRIC STATIONS

LAKE ATHABASCA	
Lake Athabasca at Ft. Chipewyan	07MD001
Lake Athabasca near Crackingstone Point	07MC003
ATHABASCA RIVER	
Athabasca River at Embarras Airport	07DD001
Embarras River below divergence	07DD003
Fletcher Channel below divergence	07DD004
Goose Island Channel below divergence	07DD005
Big Point Channel below divergence	07DD006
Athabasca River above Jackfish Creek	07DD007
Jackfish Creek above confluence Athabasca River	07DD009
BARIL LAKE	
Baril Lake at centre of lake	07KF005
BIRCH RIVER	
Birch River below Alice Creek	07KE001
CHENAL DES QUATRE FOURCHES	
Chenal Des Quatre Fourches at Quatre Fourches	07KF001
Chenal Des Quatre Fourches above Peace confluence	07KF004
Chenal Des Quatre Fourches below Four Forks	07KF006
Chenal Des Quatre Fourches at Ranger Cabin	07KF007
Chenal Des Quatre Fourches at High Rock Tower	07KF008
Mamawi Lake Channel at Dog Camp	07KF010
Lake Athabasca Channel east of Four Forks	07KF011
Grochier Channel above Four Forks	07KF012

LAKE CLAIRE	
Lake Claire near outlet to Prairie River	07KF002
MAMAWI LAKE	
Mamawi Lake at Poplar Island	07KF003
PEACE RIVER	
Peace River at Peace Point	07KC001
Peace River at Sweetgrass Landing	07KC004
Peace River at Carlson Landing	07KC003
PRAIRIE RIVER	
Prairie River at Fish Study Camp	07KF013
Prairie River near outlet Lake Claire	07KF014
REVILLON COUPE	
Revillon Coupe below confluence Riviere des Rochers	07NA004
Revillon Coupe at Ranger Cabin	07NA005
Revillon Coupe above Peace confluence	07NA006
RICHARDSON LAKE	
Richardson Lake at the outlet	07DD008
RIVIERE DES ROCHERS	
Riviere des Rochers above Peace-Slave confluence	07NA001
Riviere des Rochers at Ben Houle's Cabin	07NA002
Riviere des Rochers above confluence Revillon Coupe	07NA003
Riviere des Rochers east of Little Rapids	07NA007
Riviere des Rochers west of Little Rapids	07NA008

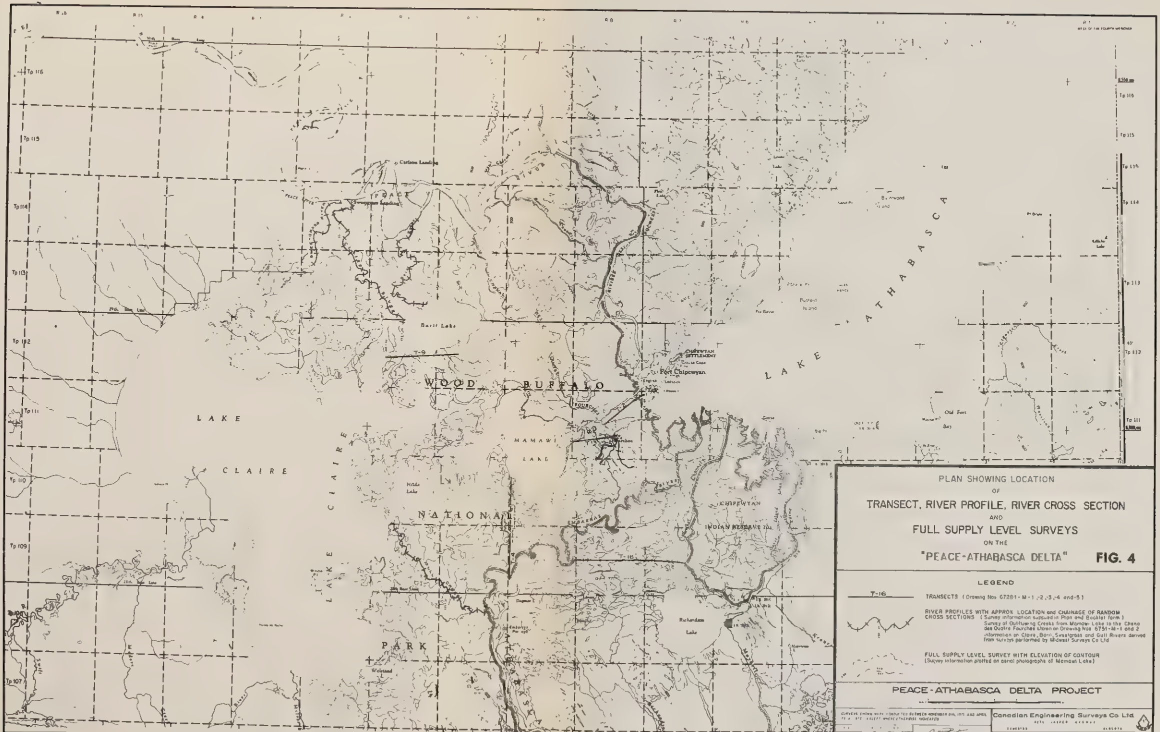


1971 HYDROMETRIC NETWORK

FIGURE 1

Figure 2. 1972 Snow Course Locations


WOOD BUFFALO NATIONAL PARK
LAKE CLAIRE
LAKE ATHABASCA
MAMAWI LAKE
PEACE RIVER
Carlson Landing
Sweetgrass Landing
Fort Chipewyan
CHIPEWYAN SETTLEMENT
Quatre Fourches
Old Fort Bay
Hilda Lake
CHIPEWYAN INDIAN RESERVE 201
ATHABASCA
Tp 116
Tp 115
Tp 114
Tp 113
Tp 112
Tp 111
Tp 110
Tp 109
Tp 107
R 16
LEGEND
TYPICAL BM
PEACE-ATHABASCA DELTA PROJECT
ICE THICKNESS AND DEPTH OF WATER STUDY FOR WINTER ECOLOGY
FIG. 3
Canadian Engineering Surveys Co Ltd


LAKE ATHABASCA
LAKE CLAIRE
WOOD BUFFALO NATIONAL PARK
MAMAWI LAKE
Baril Lake
Fort Chipewyan
CHIPEWYAN SETTLEMENT
CHIPEWYAN INDIAN RESERVE 201
Richardson Lake
Old Fort Bay
Carlson Landing
Sweetgrass Landing
PEACE
RIVER
T-9
T-16
Tp 116
Tp 115
Tp 114
Tp 113
Tp 112
Tp 111
Tp 110
Tp 109
Tp 107
PLAN SHOWING LOCATION
OF
TRANSECT, RIVER PROFILE, RIVER CROSS SECTION
AND
FULL SUPPLY LEVEL SURVEYS
ON THE
"PEACE-ATHABASCA DELTA"
FIG. 4
LEGEND
T-16
TRANSECTS (Drawing Nos 67281-M-1,-2,-3,-4 and-5)
RIVER PROFILES WITH APPROX LOCATION and CHAINAGE OF RANDOM CROSS SECTIONS (Survey information supplied in Plan and Booklet form)
Survey of Outflowing Creeks from Mamawi Lake to the Chenal des Quatre Fourches shown on Drawing Nos 6751-M-1 and 2
Information on Claire, Baril, Sweetgrass and Gull Rivers derived from surveys performed by Midwest Surveys Co Ltd
FULL SUPPLY LEVEL SURVEY WITH ELEVATION OF CONTOUR
(Survey information plotted on aerial photographs of Mamawi Lake)
PEACE-ATHABASCA DELTA PROJECT
Canadian Engineering Surveys Co Ltd

APPENDIX K-1

HYDROMETRIC STATIONS

LAKE ATHABASCA	
Lake Athabasca at Ft. Chipewyan	07MD001
Lake Athabasca near Crackingstone Point	07MC003
ATHABASCA RIVER	
Athabasca River at Embarras Airport	07DD001
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Big Point Channel below divergence	07DD006
Athabasca River above Jackfish Creek	07DD007
Jackfish Creek above confluence Athabasca River	07DD009
BARIL LAKE	
Baril Lake at centre of lake	07KF005
BIRCH RIVER	
Birch River below Alice Creek	07KE001
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Chenal Des Quatre Fourches at Ranger Cabin	07KF007
Chenal Des Quatre Fourches at High Rock Tower	07KF008
Mamawi Lake Channel at Dog Camp	07KF010
Lake Athabasca Channel east of Four Forks	07KF011
Grochier Channel above Four Forks	07KF012

LAKE CLAIRE

Lake Claire near outlet to Prairie River	07KF002

MAMAWI LAKE

Mamawi Lake at Poplar Island	07KF003

PEACE RIVER

Peace River at Peace Point	07KC001
Peace River at Sweetgrass Landing	07KC004
Peace River at Carlson Landing	07KC003

PRAIRIE RIVER

Prairie River at Fish Study Camp	07KF013
Prairie River near outlet Lake Claire	07KF014

REVILLON COUPE

Revillon Coupe below confluence Riviere des Rochers	07NA004
Revillon Coupe at Ranger Cabin	07NA005
Revillon Coupe above Peace confluence	07NA006

RICHARDSON LAKE

Richardson Lake at the outlet	07DD008

RIVIERE DES ROCHERS

Riviere des Rochers above Peace-Slave confluence	07NA001
Riviere des Rochers at Ben Houle's Cabin	07NA002
Riviere des Rochers above confluence Revillon Coupe	07NA003
Riviere des Rochers east of Little Rapids	07NA007
Riviere des Rochers west of Little Rapids	07NA008

DESCRIPTION OF HYDROMETRIC STATION

Station Name Lake Athabasca at Fort Chipewyan - Station 07MD001

Latitude 58° 42' 40" N. Longitude 111° 08' 50" W. . Sec 8 Twp 112 Rge 7 W4

Established
Re-established
Re-established

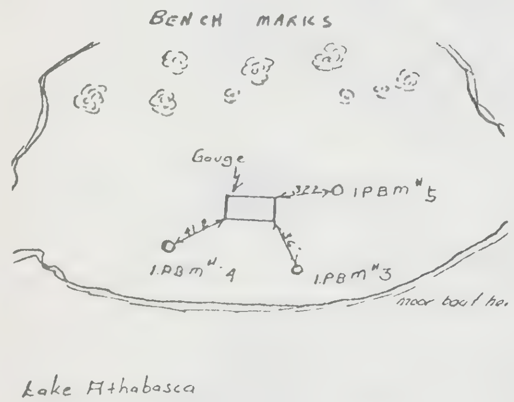
Observer

Period of Observation

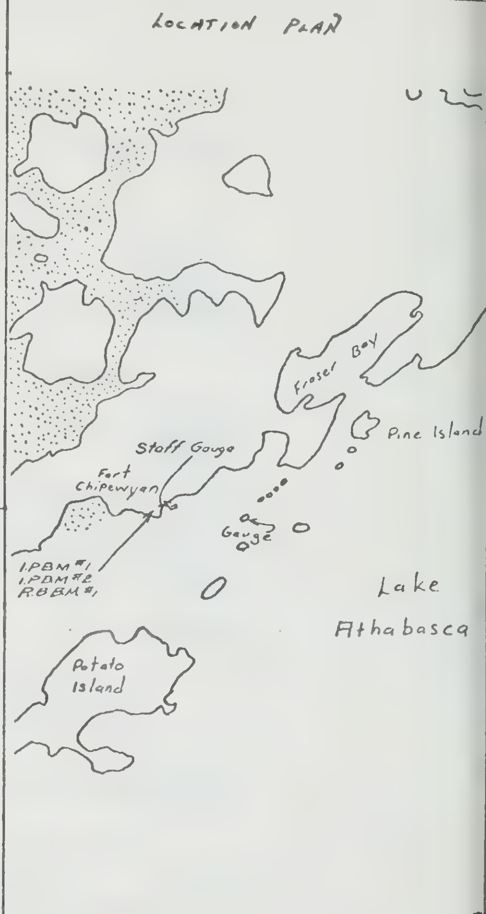
Location of Station On Island Rock Point about one mile east of Chipewyan.

Description of Equipment Recording gauge activated by a bubbler since 1968.

Remarks Refer to W.S.C. Report "Lake Athabasca Water Levels (1930 - 1970)" for complete data review.



STATION EQUIPMENT



LAKE ATHABASCA AT FORT CHIPEWYAN - STATION NO. 07MD001

DAILY WATER LEVEL IN FEET FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	675.39	675.94	683.18	683.95	684.63	684.33	683.87	682.22	681.42	681.09	1
2	---	---	675.43	675.79	682.86	684.01	684.38	684.48	684.92	682.42	681.46	681.08	2
3	---	---	675.42	675.86	682.80	684.22	684.23	684.51	684.37	682.79	681.47	681.07	3
4	---	---	675.24	676.18	683.13	683.90	684.23	684.59	683.61	682.66	681.38	680.93	4
5	678.97	676.20	675.31	676.12	683.15	683.40	683.98	684.72	682.98	681.98	681.65	680.89	5
6	678.92	676.25	675.56	676.24	683.38	684.01	684.09	684.48	682.90	681.92	681.36	680.97	6
7	678.95	676.04	675.84	676.24	682.81	634.68	684.05	684.77	682.13	682.20	681.15	680.79	7
8	678.95	676.11	675.84	676.57	682.15	684.53	683.60	684.22	682.04	682.27	681.03	680.77	8
9	678.91	675.95	675.85	676.77	682.55	684.29	684.40	683.29	682.85	681.99	681.05	680.72	9
10	678.52	676.01	675.82	676.88	682.74	684.20	684.75	682.81	683.21	682.04	680.92	680.81	10
11	678.07	676.15	675.71	677.00	683.03	684.13	684.73	683.25	683.33	682.25	681.06	680.83	11
12	---	676.10	675.66	677.07	683.49	683.83	684.21	684.16	682.97	682.19	681.10	680.81	12
13	---	676.01	675.73	677.15	683.64	684.24	684.55	684.50	682.93	681.97	680.91	680.82	13
14	---	675.78	675.69	677.49	683.75	684.33	684.62	684.32	682.64	681.92	680.91	680.77	14
15	---	675.84	675.58	677.80	683.72	684.28	684.67	684.23	683.12	682.07	680.96	680.67	15
16	---	675.59	675.55	678.09	683.90	684.17	683.89	683.83	683.16	681.39	681.10	680.50	16
17	---	675.72	675.44	678.43	684.80	684.40	685.16	683.54	683.27	681.91	680.88	680.46	17
18	---	675.73	675.49	678.91	682.93	683.99	685.05	683.66	683.24	682.63	680.98	680.39	18
19	---	675.82	675.58	679.49	683.15	684.00	684.62	684.04	682.88	682.25	681.06	680.44	19
20	---	675.84	675.48	679.99	683.23	684.17	684.62	683.83	682.86	682.32	681.17	680.43	20
21	---	675.69	675.55	680.55	683.67	684.45	684.70	683.78	682.86	682.20	681.25	---	21
22	---	675.90	675.53	681.27	684.20	684.70	684.16	683.70	683.00	681.81	681.25	---	22
23	---	675.75	675.68	681.83	684.51	684.87	684.34	683.93	683.37	681.93	681.31	---	23
24	---	676.03	675.61	682.30	684.18	684.29	685.13	683.68	682.70	681.48	681.31	---	24
25	---	675.73	675.68	682.70	684.27	683.72	684.92	684.16	682.16	681.92	681.24	---	25
26	---	675.43	675.66	682.89	684.18	684.08	684.63	684.24	682.22	681.62	681.23	---	26
27	---	675.21	675.85	683.07	683.92	684.45	684.58	683.67	682.22	681.27	681.08	---	27
28	---	675.27	675.82	683.52	683.98	685.32	684.67	683.82	682.37	681.55	681.06	---	28
29	---		675.72	683.65	683.95	685.68	684.69	683.77	682.33	681.86	680.98	---	29
30	---		675.65	683.69	683.80	684.76	684.45	683.49	681.83	681.82	681.06	---	30
31	---		675.84		683.98		683.53	683.41		681.47		---	31

SUMMARY FOR THE YEAR 1970
MAXIMUM DAILY WATER LEVEL, 685.68 FT ON JUN 29

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 42 40 N
LONG 111 08 50 W

REVISED DATA TO 1970
AVAILABLE FROM DISTRIC

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

LAKE ATHABASCA AT FORT CHIPEWYAN - STATION NO. 07MD001

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	676.99	684.58	684.13	685.00	686.74	685.70	683.45	682.63	---	1
2	---	---	---	677.14	684.48A	684.22	685.16	686.63	686.41	683.50	682.45	---	2
3	---	---	---	676.82	684.03A	684.34	685.38	686.50	685.49	683.47	682.38	---	3
4	679.67A	---	---	676.92	683.93A	684.19	685.23	686.47	684.92	683.39	682.52	---	4
5	679.67	---	---	676.79	683.88A	684.76	685.48	686.80	685.12	683.41	682.39	---	5
6	679.63	---	---	677.00	683.92A	684.42	685.56	686.39	684.64	683.36	682.39	---	6
7	679.44	---	---	676.87	683.96A	684.20	685.58	686.56	684.49	682.61	682.49	682.11A	7
8	679.30	---	---	676.61	681.16A	684.47	685.39	686.15	684.42	683.33	682.40	---	8
9	679.10	---	---	676.92	684.23A	684.33	685.48	686.23	684.54	682.87	682.50	---	9
10	678.82	---	---	676.83	684.25A	684.11	685.68	686.28	684.72	683.13	682.57	---	10
11	678.61	---	---	676.75	684.17A	684.16	685.55	686.21	684.49A	683.47	682.40	---	11
12	678.64	---	---	676.73	684.66A	684.85	685.35	686.24	683.80A	682.63	682.51	---	12
13	678.56	---	---	676.72	685.05A	684.08	685.40	685.52	683.44A	683.73	682.50	682.10A	13
14	---	---	---	676.72	684.89A	684.64	685.58	686.25	684.07	683.55	682.48	---	14
15	---	675.41A	---	676.66	684.73A	684.94	686.23	686.61	684.76	683.29	682.35	681.80A	15
16	---	675.27A	676.39A	676.64	684.02A	684.74	686.10	686.24	684.46	682.89	682.55	681.94	16
17	---	---	676.31	676.77	683.49A	684.42	686.02	685.99	684.53	682.88	682.46	681.79	17
18	---	675.61A	676.22	677.08	684.43A	684.64	686.20	685.98	684.07	682.78	682.57	681.77	18
19	---	675.63A	676.31	677.26	684.41	684.54	686.25	686.07	684.11	682.87	682.58	681.76	19
20	---	---	676.29	677.58	684.45	684.39	686.48	686.17	684.34	682.78	682.54	681.63	20
21	---	---	676.34	678.15	684.58	684.53	686.67	686.02	683.96	682.65	682.59	681.61	21
22	---	---	676.35	678.72	684.42	684.85	686.86	685.63	684.31	682.70	682.59	681.58	22
23	---	---	676.50	679.34	684.30	685.32	687.23	685.35	684.58	682.67	682.59	681.58	23
24	---	---	676.51	680.23	684.67	685.30	686.70	685.39	685.15	682.69	682.60	681.55	24
25	---	---	676.50	680.83	684.37	685.42	686.64	685.41	685.45	681.55	682.56	681.42	25
26	---	---	676.68	681.50	684.33	687.14	686.92	685.24	684.30	682.45	682.57	681.37	26
27	---	---	676.80	682.63	684.40	685.48	686.81	685.47	683.73	682.70	682.59	681.42	27
28	---	---	676.64	684.04	684.28	684.74	686.81	685.47	682.98	682.52	682.60	681.38	28
29	---		676.85	684.82	684.61	685.02	686.55	685.32	683.36	682.01	682.60A	681.46	29
30	---		676.88	684.82	684.57	684.99	686.57	685.29	683.39	682.42	---	681.39	30
31	---		676.80		684.20		686.70	685.39		682.48		681.34	31

SUMMARY FOR THE YEAR 1971
MAXIMUM DAILY WATER LEVEL, 687.23 FT ON JUL 23

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 42 40 N
LONG 111 08 50 W

A-MANUAL GAUGE

REVISED DATA TO 1970
AVAILABLE FROM DISTRICT

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

Lake Athabasca at Fort Chipewyan Station No. 07MD001

Daily Elevations in Feet for the Year 1972

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	681.35	678.94	676.80	676.77	682.69	685.57	688.38	688.38	686.92			
2	681.34	678.65	676.59	676.39	682.98	686.30	688.28	688.50	.69			
3	681.33	678.33	676.58	676.56	684.04	686.49	688.34	688.18	685.89			
4	681.37	678.20	676.59	676.87	684.78	686.07	688.43	688.41	686.71			
5	681.34	678.06	676.47	677.17	684.58	686.57	688.52	688.35	.77			
6	681.24	677.94	676.69	677.00	684.91	686.36	688.58	688.24	.57			
7	681.17	677.95	676.56	677.22	684.85	686.63	688.54	688.25	.64			
8	681.25	677.80	677.36	677.34	684.78	687.13	688.53	688.26	.57			
9	681.16	677.34	676.23	677.24	684.76	686.96	688.87	688.09	.50			
10	680.87	677.15	676.38	677.40		686.80	689.60	687.97	.45			
11	680.92	677.40	676.63	677.53		686.82	688.65	688.18	.45			
12	680.89	677.48	676.61	677.40		686.69	688.54	688.27	.34			
13	680.89	677.75	676.78	677.18		687.03	688.60	687.98	.22			
14		677.70	676.72	677.11		687.07	688.44	687.88	.69			
15		678.17	676.68	677.05		686.84	688.41	687.79	.17			
16		678.04	676.61	676.75		686.82	688.60	687.68	.49			
17		677.41	676.62	676.94		687.71	688.75	687.93	.08			
18		677.27	676.84	677.17		687.41	685.65	687.90	.19			
19		677.22	676.69	677.55		687.14	688.67	.68	.81			
20		677.23	676.59	677.43		687.33	688.65	.64	.59			
21		677.02	676.74	677.77		687.48	688.90	.54	.23			
22		677.09	676.55	678.24		687.74	688.89	.58	.64			
23		677.14	676.29	678.31		687.93	688.70	.53	685.45			
24		677.05	676.41	678.95		687.97	689.01	.48	684.75			
25		677.07	676.40	679.21		688.06	688.95	.13	685.14			
26		677.02	676.16	679.48	686.39	687.95	688.53	686.89				
27	679.54	676.84	676.15	680.53	686.20	687.89	688.44	.88				
28	679.59	676.77	676.15	681.58	686.56	687.90	688.19	687.28				
29	679.44	676.80	676.16	682.19	686.63	687.79	687.88	686.42				
30	679.16		676.28	682.49	686.52	687.85	688.47	687.17				
31	679.06		676.28		687.01		688.23	686.93				

DESCRIPTION OF HYDROMETRIC STATION

Station Name Lake Athabasca near Crackingstone Point - Station No. 07MC003

Latitude 59° 23' N. Longitude 108° 53' W. . Sec Twp Rge

Established 1956
Re-established
Re-established

Observer

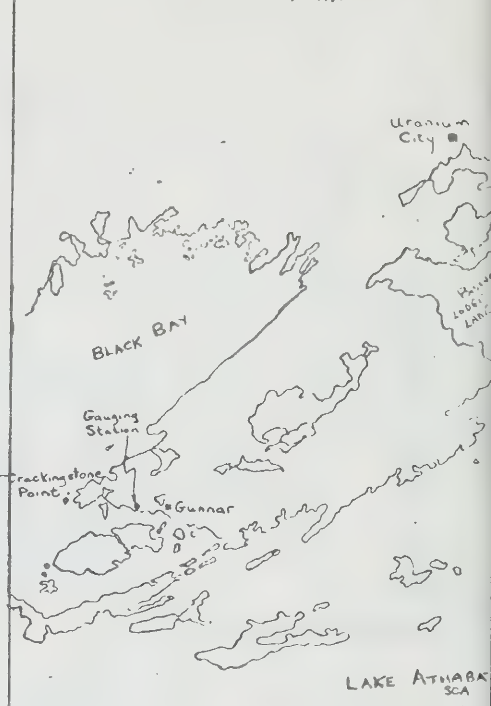
Period of Observation At Gold Fields from 1936 to 1942 and from 1952 to 1954; at Crackingstone Point from 1956 to present

Location of Station Sixteen miles southwest of Uranium City, Saskatchewan, at Gunnar Mines (now closed), about 500 feet southeast of Community Centre.

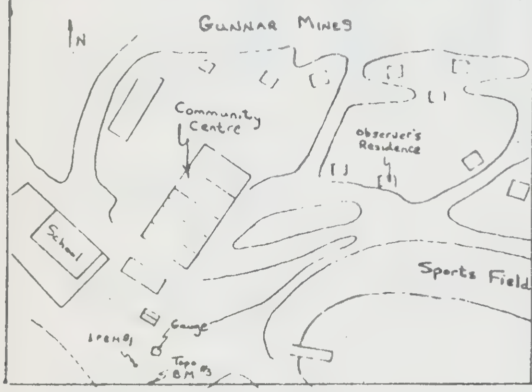
Description of Equipment Recorder activated by a pressure gauge.

Remarks Refer to W.S.C. Report "Lake Athabasca Water Levels (1930 - 1970)" for complete data review.

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

LAKE ATHABASCA NEAR CRACKINGSTONE POINT - STATION NO. 07MC003

DAILY WATER LEVEL IN FEET FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	684.18	684.55	683.72	682.79	---	681.72	1
2	---	---	---	---	---	---	684.21	684.51	683.54	682.72	---	681.71	2
3	---	---	---	---	---	---	684.26	684.50	683.49	682.65	---	681.72	3
4	---	---	---	---	---	684.07	684.32	684.47	683.57	682.65	681.96	681.75	4
5	---	681.66	---	---	---	684.10	684.42	684.40	683.65	682.63	681.86	681.74	5
6	---	---	---	---	---	684.06	684.48	684.43	683.63	682.67	681.91	681.72	6
7	---	---	---	---	---	684.02	684.54	684.37	683.65	682.64	681.91	681.76	7
8	---	---	---	---	---	683.97	684.63	684.47	683.59	682.60	681.92	681.76	8
9	---	---	---	---	---	684.03	684.61	684.52	683.51	682.61	681.87	681.75	9
10	---	---	---	---	---	684.02	684.72	684.53	683.39	682.55	681.88	681.75	10
11	---	---	---	---	---	684.06	684.68	684.49	683.31	682.50	681.83	681.75	11
12	---	---	---	---	---	684.15	684.79	684.39	683.35	682.44	681.82	681.75	12
13	---	---	---	---	---	684.13	684.81	684.32	683.35	682.44	681.85	681.74	13
14	---	---	---	---	---	684.20	684.82	684.28	683.36	682.42	681.85	681.75	14
15	---	---	---	---	---	684.25	684.84	684.26	683.25	682.38	681.83	681.75	15
16	---	---	---	---	---	684.22	684.75	684.28	683.21	682.41	681.78	681.78	16
17	---	---	---	---	---	684.20	684.82	684.30	683.13	---	681.82	681.77	17
18	---	---	---	---	---	684.28	684.82	684.18	683.09	---	681.77	681.78	18
19	---	---	---	---	---	684.28	684.87	684.11	683.11	---	681.76	681.77	19
20	---	---	---	---	---	684.29	684.90	684.08	683.09	---	681.73	681.75	20
21	---	---	---	---	---	684.24	684.87	684.09	683.06	---	681.73	681.73	21
22	---	---	---	---	---	684.21	684.90	684.05	683.01	---	681.77	681.75	22
23	---	---	---	---	---	684.16	684.85	683.98	682.94	---	681.77	681.76	23
24	---	---	---	---	---	684.18	684.77	683.99	682.88	---	681.73	681.77	24
25	---	---	682.18	---	---	684.28	684.77	683.91	682.94	---	681.72	681.80	25
26	---	---	---	---	---	684.30	684.74	683.86	682.86	---	681.73	681.77	26
27	---	---	---	---	---	684.29	684.72	683.94	682.83	---	681.81	681.74	27
28	---	---	---	---	---	684.21	684.69	683.92	682.83	---	681.76	681.77	28
29	---		---	---	---	684.11	684.67	683.86	682.80	---	681.83	681.75	29
30	---		---	---	---	684.16	684.68	683.84	682.85	---	681.77	681.76	30
31	---		---		---		684.74	683.84		---		681.77	31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 22 55 N
LONG 108 52 50 W

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

LAKE ATHABASCA NEAR CRACKINGSTONE POINT · STATION NO. 07MC003

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	-	681.96	682.22	682.52	683.17	683.77	684.90	686.52	685.20	683.81	682.68	682.39	1
2	---	681.95	682.21	682.54	--	683.81	684.94	686.52	685.02	683.74	682.67	682.32	2
3	---	681.98	---	682.58	--	683.70	684.98	686.53	685.05	683.73	682.70	682.40	3
4	---	682.00	---	682.57	683.57	683.71	685.07	686.51	685.11	683.68	682.63	682.40	4
5	---	682.03	---	682.60	---	683.67	685.13	686.39	685.05	683.65	682.64	682.38	5
6	681.78	682.02	-	682.58	683.76	683.67	685.18	686.45	685.06	683.65	682.63	682.36	6
7	681.81	682.00	---	682.60	--	683.56	685.16	686.38	685.01	683.67	682.59	682.35	7
8	681.82	682.03	---	682.63	--	683.55	685.26	686.39	684.97	683.58	682.60	682.32	8
9	681.83	682.05	--	682.57	---	683.98	685.31	686.34	684.90	683.60	682.55	682.32	9
10	681.84	682.00	---	682.58	683.89	684.05	685.33	686.29	684.82	683.53	682.50	682.35	10
11	681.83	681.99	---	---	---	684.05	685.38	686.25	684.79	683.41	682.58	682.35	11
12	681.81	681.99	---	---	683.79	684.04	685.47	686.14	684.82	683.48	682.52	682.33	12
13	681.83	682.05	- -	---	---	684.06	685.47	686.26	684.83	683.32	682.51	682.29	13
14	681.85	682.07	--	---	---	684.00	685.51	686.09	684.66	683.27	682.52	682.29	14
15	681.81	682.08	---	--	683.90	683.95	685.50	685.95	684.55	683.27	682.55	682.33	15
16	681.79	682.11	682.40	---	---	684.03	685.58	685.95	684.55	683.30	682.48	682.27	16
17	681.84	682.10	682.41	---	683.95	684.12	685.76	685.92	684.66	683.27	682.49	682.29	17
18	681.83	682.10	682.43	---	---	684.15	685.92	685.89	684.51	683.27	682.42	682.29	18
19	681.84	682.13	682.43	---	---	684.19	686.10	685.84	684.39	683.22	682.38	682.26	19
20	681.89	682.15	682.43	---	683.97	684.26	686.22	685.73	684.31	683.18	682.39	682.29	20
21	681.91	682.17	682.44	---	---	684.31	686.30	685.68	684.35	683.18	682.38	682.25	21
22	681.93	682.17	682.45	---	683.98	684.36	686.35	685.72	684.25	683.12	682.39	682.23	22
23	681.92	682.20	682.46	---	---	684.40	686.39	685.78	684.15	683.10	682.38	682.21	23
24	681.90	682.20	682.47	---	684.00	684.48	686.52	685.70	683.96	683.05	682.35	682.19	24
25	681.92	682.23	682.47	---	---	684.54	686.60	685.65	683.80	683.09	682.39	682.19	25
26	681.91	682.22	682.46	---	---	684.32	686.59	685.64	683.91	682.93	682.39	682.18	26
27	681.92	682.23	682.50	---	---	684.59	686.60	685.55	683.94	682.84	682.36	682.17	27
28	681.92	682.22	682.52	---	---	684.79	686.58	685.50	684.00	682.87	682.35	---	28
29	681.93		682.50	---	---	684.83	686.63	685.46	683.90	682.93	682.39	---	29
30	681.97		682.52	---	---	684.85	686.58	685.40	683.87	682.85	682.40	---	30
31	681.98		682.54		---		686.56	685.33		682.78		---	31

SUMMARY FOR THE YEAR 1971
MAXIMUM DAILY WATER LEVEL, 686.63 FT ON JUL 29
MINIMUM DAILY WATER LEVEL, 681.78 FT ON JAN 6

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 22 55 N
LONG 108 52 50 W

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

Lake Athabasca near Crackingstone Point Station No. 07MC003

Daily Elevations or Gauge Heights in Feet for the Year 1972

Day	January	February	March	April	May	June	July	August	September	October	November	December
1					682.79	686.37	688.12	688.20	686.92	685.35	684.21	
2					683.08	686.35	688.27	688.07	686.74	685.38	684.22	
3						686.36	688.22	688.04E	686.78	685.39	684.24	
4					683.10	686.39	688.23E	688.01E	686.67		684.15	
5					683.21	686.29	688.24E	687.98E	686.61	685.13	684.15	
6					683.39	686.42	688.25E	687.95E	686.61	685.16	684.11	
7					683.64		688.26E	687.92E	686.53	685.11	684.13	
8					683.82	686.30	688.27E	687.89E	686.45	685.04	684.14	
9	682.00				684.04	686.49	688.28E	687.86E	686.20	684.88	684.12	
10					684.29	686.48	688.29E	687.83E	686.35	684.94	684.07	
11					684.56	686.50	688.30E	687.80E	686.37	684.98	684.07	
12					684.67	686.49	688.31E	687.77E	686.27	684.94	684.07	
13					685.02	686.46	688.32E	687.74E	687.19	684.86	684.05	
14						868.56	688.33E	687.71E	686.10	684.79	684.05	
15					685.09	686.55	688.34E	687.68E	686.06	684.65	684.09	
16			682.06		685.18	686.54	688.35E	687.65E	685.98	684.65	684.05	
17					685.35	686.54	688.36E	687.62E	685.94	684.67	684.03	
18					685.44	868.79	688.37E	687.60		684.69	684.06	
19					685.56	687.07	688.38E	687.55		684.62	684.09	
20					685.63	687.28	688.39E	687.60		684.60	684.08	
21					685.75	687.34	688.41E	687.58	685.49	684.54	684.10	
22					685.84	687.29	688.43E	687.55	685.57	684.51	684.12	
23					685.90	687.50	688.45E	687.47E	685.56	684.54	684.15	
24					685.92	687.58	688.46	687.40		684.49	684.12	
25					686.01	687.78	688.35	687.37E	685.42	684.32	684.15	
26					686.02	687.84	688.44	687.35	685.42	684.37	684.12	
27					686.06	688.02	688.43	687.17	685.30	684.40	684.16	
28					686.13	688.18	688.28	687.35	685.27	684.37	684.15	
29				682.72	686.10	688.16E	688.22	687.16E	685.25	684.40		
30				682.77	686.16	688.14E	688.24	686.96	685.16	684.43		
31					686.17		688.22E	686.84		684.29		

DESCRIPTION OF HYDROMETRIC STATION

Station Name Athabasca River at Embarras Airport - Station 07DD01

Latitude 58° 12' 15" N. Longitude 111° 23' 32" W. N.E Sec 15 Twp 106 Rge W4th Mer.

Established 1964
Re-established
Re-established

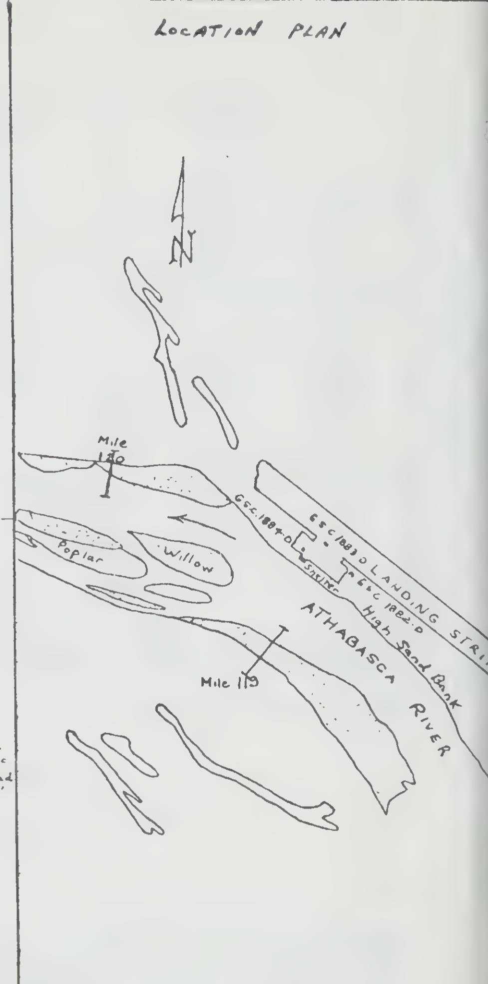
Observer

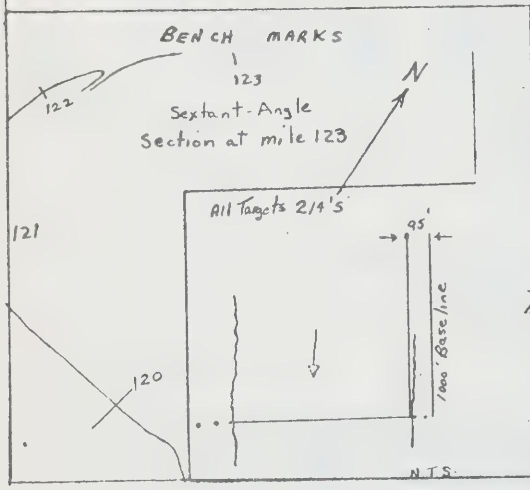
Period of Observation 1959-60, 1964 to present, water sediment data collected in 1971 (seasonal)

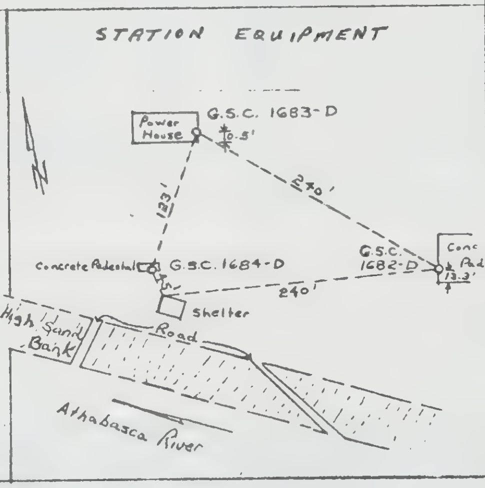
Location of Station In N.E. 1/4 sec. 15, TP. 106, RGE 9, W. 4th Mer., on the right bank at Embarras airstrip at Mile 119.2 from waterways (Chart 6301).

Description of Equipment A-35 Recorder activated by bubbler

Remarks Station moved to present site May 1964. Station datum referred to G.S.C. (1965).
Records of 1959-60, are not comparable to those of 1964 to present due to datum differences.







ATHABASCA RIVER AT EMBARRAS AIRPORT - STATION NO. 07DD001

DAILY WATER LEVEL IN FEET FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	704.22	---	---	---	---	709.09	713.05	708.76	705.68	707.00	---	---	1
2	704.22	---	---	---	---	709.05	715.90	709.55	705.82	706.81	---	---	2
3	704.20	---	---	---	---	709.28	718.78	710.45	706.11	706.61	---	---	3
4	704.10	---	---	---	---	709.23	720.72	710.73	706.43	706.43	---	---	4
5	704.06	703.66	---	---	---	708.69	721.21	710.57	706.78	706.27	---	---	5
6	---	---	---	---	---	708.07	720.68	710.15	707.13	706.13	---	---	6
7	---	---	---	704.18	---	707.51	719.74	709.61	707.25	706.02	---	---	7
8	---	---	---	704.25	---	707.07	718.60	709.14	707.17	---	---	---	8
9	---	---	703.86	704.31	---	706.84	717.34	708.70	707.05	---	---	---	9
10	---	---	703.85	704.36	---	707.51	716.13	708.40	706.99	---	---	---	10
11	---	---	703.83	704.45	---	709.16	715.12	708.18	706.90	---	---	---	11
12	---	---	703.81	704.60	---	709.73	714.54	708.10	706.76	---	---	---	12
13	---	---	703.78	704.78	---	709.53	714.23	708.03	706.58	---	---	---	13
14	---	---	703.77	705.03	---	709.38	713.91	707.87	706.35	---	---	---	14
15	---	---	703.75	705.37	707.70	709.50	713.53	707.76	706.12	---	---	---	15
16	---	---	703.73	705.83	707.70	709.64	713.05	707.63	705.91	---	---	---	16
17	---	---	703.72	706.75	707.78	709.62	712.45	707.42	705.73	---	---	---	17
18	---	---	703.72	708.05	708.18	709.73	711.79	707.11	705.60	---	---	---	18
19	---	---	703.70	709.57	708.99	709.47	711.11	706.88	705.48	---	---	---	19
20	---	---	703.70	712.02	709.67	709.03	710.43	706.79	705.38	---	---	---	20
21	---	---	---	714.08	709.77	709.08	709.78	706.73	705.29	---	---	---	21
22	---	---	---	---	709.58	711.71	709.37	706.73	705.18	---	---	---	22
23	---	---	---	---	709.22	713.29	709.20	706.58	705.09	---	---	---	23
24	---	---	---	---	709.12	712.59	709.23	706.35	705.02	---	---	---	24
25	---	---	---	---	709.39	712.18	709.40	706.22	705.30	---	---	---	25
26	---	---	---	---	709.72	712.12	709.28	706.10	706.06	---	---	---	26
27	---	---	---	---	709.50	711.97	709.19	705.87	706.82	---	---	---	27
28	---	---	---	---	709.23	711.65	709.12	705.71	707.08	---	---	---	28
29	---		---	---	709.06	711.46	708.92	705.59	707.12	---	---	---	29
30	---		---	---	709.01	711.41	708.64	705.57	707.10	---	---	---	30
31	---		---		709.07		708.53	705.58		---		---	31

SUMMARY FOR THE YEAR 1970
MAXIMUM DAILY WATER LEVEL, 721.21 FT ON JUL 5

MAXIMUM INSTANTANEOUS WATER LEVEL, 721.28 FT
AT 1130 MST ON JUL 5

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 12 15 N
LONG 111 23 32 W

NATURAL FLOW

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

ATHABASCA RIVER AT EMBARRAS AIRPORT - STATION NO. 07DD001

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	76600 E	27900	87800	59800	27500	18600	13800 B	9500 B	1
2	---	---	---	---	72200 E	29800	87800	55700	27200	18700	13500 B	9200 B	2
3	---	---	---	---	68300 E	31800	82500	53500	27700	20000	13300 B	8900 B	3
4	---	---	---	---	63100 E	33500	75800	51900	27300	21800	13000 B	8600 B	4
5	---	---	---	---	60500 E	33300	72900	49800	26600	22600	12700 B	8300 B	5
6	---	---	---	---	57300 E	32200	74700	47800	26400	22200	12300 B	8000 B	6
7	---	---	---	---	55200 A	32300	83600	47000	26400	21500	12000 B	7800 B	7
8	---	---	---	---	52500	32800	103000	46300	26600	20800	11800 B	7500 B	8
9	---	---	---	---	50100	33600	114000	46200	26400	20500	11600 B	7300 B	9
10	---	---	---	---	48400	35800	114000	46100	25300	20500	11500 B	7100 B	10
11	---	---	---	---	47100	41700	114000	45000	23700	20400	11400 B	7000 B	11
12	---	---	---	---	45500	57000	119000	43700	22400	20300	11400 B	7100 B	12
13	---	---	---	---	43700	64700	121000	43300	21300	20000	11500 B	7300 B	13
14	---	---	---	---	41900	78800	120000	43300	21100	20200	11400 B	7400 B	14
15	---	---	---	---	40300	93300	125000	44000	22000	20800	11300 B	7200 B	15
16	---	---	---	---	38600	92700	138000	43000	21900	21500	11100 B	7000 B	16
17	---	---	---	---	36600	82100	148000	41400	21600	21200	11000 B	6800 B	17
18	---	---	---	---	34400	73500	146000	40300	22500	20200	10900 B	6700 B	18
19	---	---	---	---	32700	73900	135000	39900	22500	19300	10800 B	6600 B	19
20	---	---	---	---	32900	81200	121000	39400	23900	18800	10900 B	6400 B	20
21	---	---	---	---	35400	82800	109000	38600	24000	18300	11000 B	6300 B	21
22	---	---	---	---	34600	85400	100000	37400	22600	17900	11100 B	6300 B	22
23	---	---	---	---	32400	83500	91100	36100	21300	17500	11200 B	6200 B	23
24	---	---	---	---	30100	75900	82800	34800	20000	17100	11100 B	6100 B	24
25	---	---	---	---	28100	68000	76600	33400	19300	16800	11000 B	6000 B	25
26	---	---	---	---	26600	63500	72700	32000	19100	16200	10800 B	6000 B	26
27	---	---	---	---	25500	61800	69700	30600	19100	15500	10600 B	5900 B	27
28	---	---	---	---	24600	63400	67800	29700	19100	15000	10300 B	5900 B	28
29	---		---	---	24500	71500	67200	29700	19100	14700	10000 B	5800 B	29
30	---		---	---	24900	82500	67600	29500	18900	14400 B	9800 B	5800 B	30
31	---		---		26100		64900	29100		14000 B		5900 B	31
TOTAL	---	---	---	---	1310700	1800200	3052500	1288300	692800	587300	344100	217900	TOTAL
MEAN	---	---	---	---	42300	60000	98500	41600	23100	18900	11500	7030	MEAN
AC-FT	---	---	---	---	2600000	3570000	6050000	2560000	1370000	1160000	683000	432000	AC-FT
MAX	---	---	---	---	76600	93300	148000	59800	27700	22600	13800	9500	MAX
MIN	---	---	---	---	24500	27900	64900	29100	18900	14000	9800	5800	MIN

SUMMARY FOR THE MONTHS MAY TO DEC

MEAN DISCHARGE, 37900 CFS
TOTAL DISCHARGE, 18400000 AC-FT
MAXIMUM DAILY DISCHARGE, 148000 CFS ON JUL 17
MINIMUM DAILY DISCHARGE, 5800 CFS ON DEC 29

MAXIMUM INSTANTANEOUS DISCHARGE
149000 CFS AT 2100 MST ON JUL 17

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 12 15 N
LONG 111 23 32 W

A-MANUAL GAUGE
B-ICE CONDITIONS
E-ESTIMATED

NATURAL FLOW

DESCRIPTION OF HYDROMETRIC STATION

Station Name Embarras River below Divergence - station No. 07DD003

Latitude 58° 25' 20" N. Longitude 111° 33' 05" W. Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

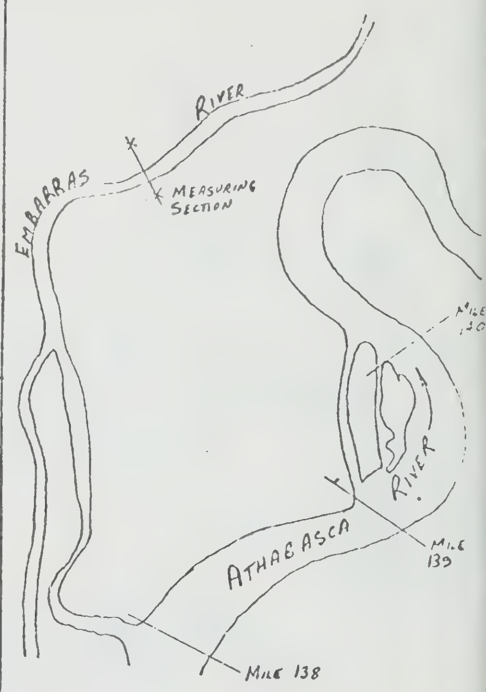
Period of Observation 1971 to present, water sediment data collected in 1971 also.

Location of Station On right bank, about two and one-quarter miles below divergence from the Athabasca River at mile 138 on the Athabasca River navigation route.

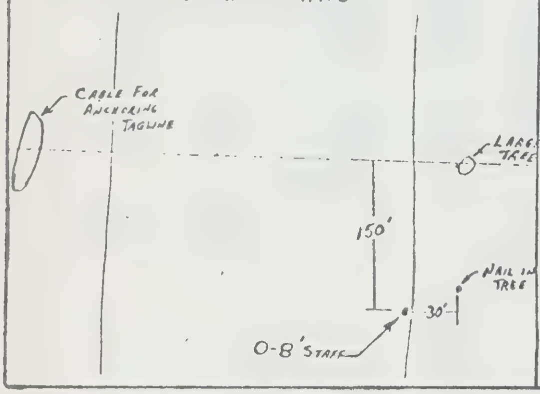
Description of Equipment Staff gauge.

Remarks This is one of the study stations in the Peace-Athabasca Delta Study.

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

Embarras River below Divergence - Station No. 07DD0003

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
May 9	2.40	4.00	8,210
Jun 3	1.54	-0.03	3,470
Jun 15	2.91	9.27	17,000
Jul 7	2.66	7.86	13.900
Jul 18	3.46	13.80	27,400
Aug 4	2.33	4.12	8,200
Aug 18	2.09	1.88	5,300
Aug 31	1.60	-0.41	2,620
Sep 29			573
Oct 23	0.95		554
Dec 20	1.04	-3.27	116

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharg cfs
Jan 31			0 e
Apr 14			0 e
Jun 21	2.47		14,300
Jul 4	2.43		1,420
Jul 20	1.97		6,270
Aug 8	1.77		4,110
Aug 22	1.55		2,825

DESCRIPTION OF HYDROMETRIC STATION

Station Name Fletcher Channel Below Divergence - Station No 07DD004

Latitude 58° 27' 55" N. Longitude 111° 04' 30" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

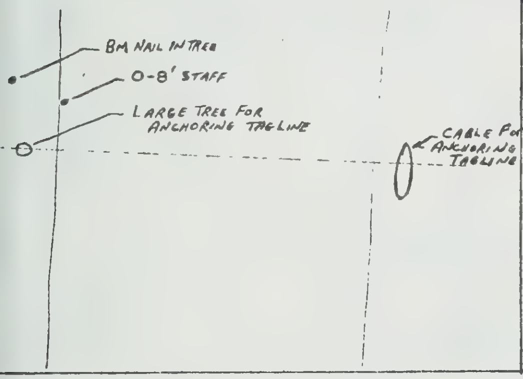
Period of Observation 1971 to the present. Water sediment data collected in 1971.

Location of Station On left bank, one mile below divergence from Athabasca River, about mile 163 on the Athabasca River Navigation Route.

Description of Equipment Staff gauge.

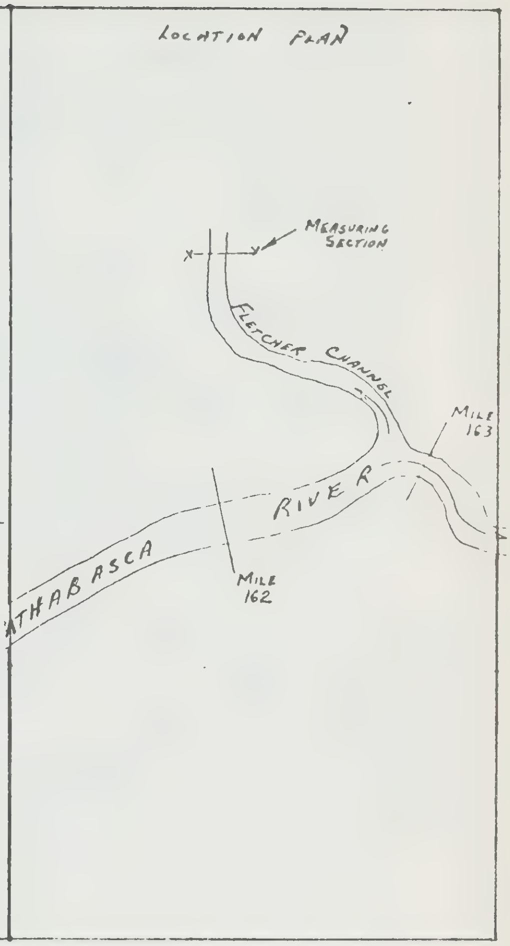
Remarks This is one of the stations in the Peace-Athabasca Delta Study.

BENCH MARKS



STATION EQUIPMENT

LOCATION PLAN



Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
May 9	2.56	4.75	9,610
Jun 3	1.91	1.70	5,130
Jun 16	3.95	6.37	14,100
Jul 7	2.97	6.47	13,000
Jul 18	5.29	8.53	27,700
Aug 4	2.47	5.34	9,470
Aug 18	1.91	3.66	6,690
Sep 1	1.54	2.11	4,660
Sep 30	1.19	0.52	3,030
Oct 22	1.10	0.26	2,750
Dec 20	0.41	-0.79	806

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jan 31	0.37	-0.67	694
Apr 14	0.55	1.18	1,130
Jun 3	1.93	3.91	9,210
Jun 22	1.85		9,266
Jul 5	3.51		18,100
Jul 19	4.38		10,000
Aug 8	1.93		6,860
Aug 23	1.73		5,643

DESCRIPTION OF HYDROMETRIC STATION

Station Name Goose Island Channel below Divergence, station 07DD005

Latitude 58° 28' 15" N. Longitude 110° 51' 20" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

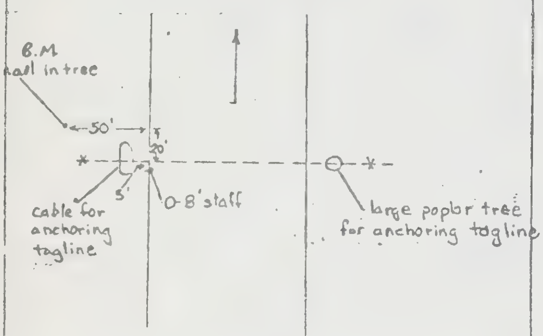
Period of Observation 1971 to the present; water sediment data collected 1971.

Location of Station On left bank approximately three-quarters of a mile below divergence from Athabasca River at mile 174 on the Athabasca River navigation route.

Description of Equipment Staff gauge

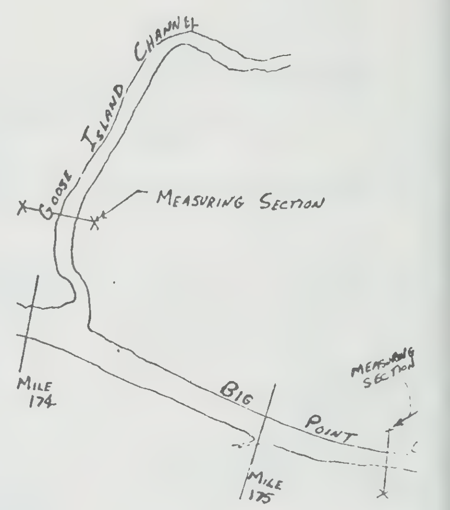
Remarks This is one of the stations in the Peace-Athabasca Delta Study

BENCH MARKS



STATION EQUIPMENT

LOCATION PLAN



Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
May 8	3.31	3.29	21,400
Jun 2	1.84	1.06	10,900
Jun 16	3.43	4.01	23,100
Jul 7	3.35	4.31	22,700
Jul 19	4.83	6.54	35,100
Aug 4	2.59	4.09	17,800
Aug 18	2.12	2.90	13,600
Sep 1	1.65	1.85	10,200
Sep 30	1.45	0.28	8,000
Oct 22	1.39		7,690
Dec 31	0.48	-0.43	2,360

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Feb 1	0.50	-0.16	2,400
Apr 13	0.69	1.31	3,580
Jun 3	1.641		11,000
Jun 22	1.29		9,284
Jul 7	3.20		25,100
Jul 18	2.14		15,800
Aug 7	2.10		11,570
Aug 24	1.55		10,200

DESCRIPTION OF HYDROMETRIC STATION

Station Name Big Point Channel below Divergence, station 07DD006

Latitude 58° 28' 55" N. Longitude 110° 48' 15" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

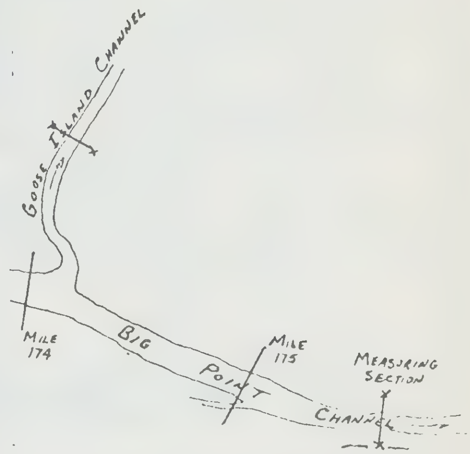
Period of Observation 1971 to present; water sediment data collected in 1971.

Location of Station On right bank at mile 175.5 on the Athabasca River navigation channel.

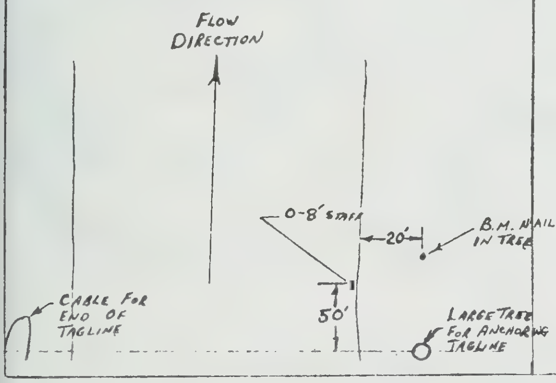
Description of Equipment Staff gauge

Remarks This is one of the stations in the Peace-Athabasca Delta Study

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
May 8	3.02	4.63	22,500
Jun 2	1.91	2.21	12,100
Jun 17	3.12	5.20	24,700
Jul 7	3.11	5.71	24,700
Jul 19	4.12	7.92	36,600
Aug 5	2.62	5.34	20,800
Aug 19	2.17	4.12	16,200
Sep 1	1.67	4.17	11,800
Sep 30	1.46	1.53	9,120
Oct 22	1.49	1.27	9,340
Dec 21	0.51	0.97	2,830

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Feb 1	0.54	1.16	2,910
Apr 13	0.75	2.56	4,390
Jun 3	1.04		7,400
Jun 22	1.33		7,560
Jul 7	1.88		28,800
Jul 18	2.42		20,400
Aug 8	1.88		15,000
Aug 24	1.56		11,744

DESCRIPTION OF HYDROMETRIC STATION

Station Name Athabasca River Above Jackfish Creek - Station No. 07DD007

Latitude 58° 25' N. Longitude 110° 55' W. . Sec Twp Rge

Established 1971
Re-established
Re-established

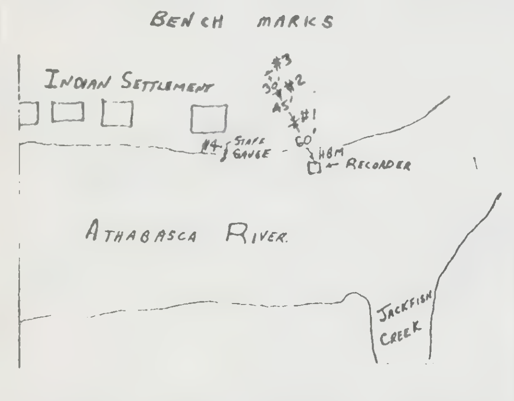
Observer

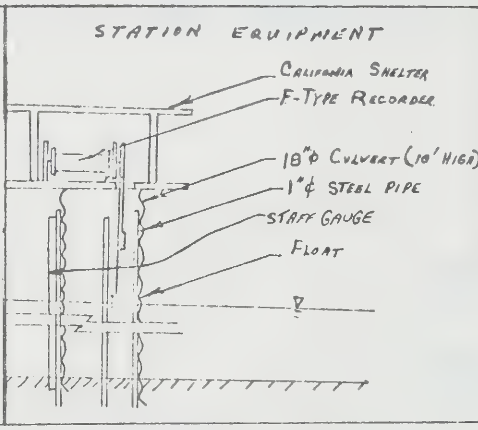
Period of Observation 1971 to present (seasonal)

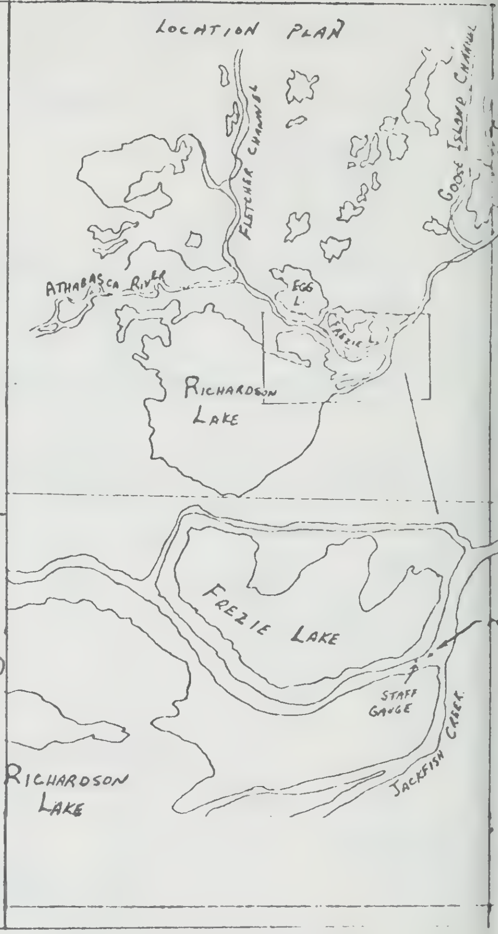
Location of Station Twenty-two miles south and nine miles east of Fort Chipewyan, located on the left bank of the Athabasca River three-hundred feet east of Indian settlement.

Description of Equipment Staff gauge installed July 6/71. (F-type recorder originally installed, was knocked out June 25/71.

Remarks This station operated for the Peace-Athabasca Delta Study.







Athabasca River Above Jackfish Creek - Station No. 07DD007

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						2.74			3.48 a			
2						2.88			3.88 a			
3						3.09			3.53 a			
4						3.18			3.74 a			
5						3.52			3.29 a			
6						3.33						
7						3.22						
8						3.30						
9						3.30						
10						3.38						
11						3.60		5.64 a				
12						4.22		5.46 a				
13						4.94		5.11 a				
14						5.53		5.09 a				
15						6.03 a		5.20 a				
16						6.63 a		5.04 a				
17						6.50 a	9.48 a	4.94 a				
18						6.30 a	9.61 a	4.86 a				
19							10.38 a	4.77 a				
20							10.92 a	4.69 a				
21							9.84 a	4.64 a		1.70 a		
22					3.77 a	6.72 a	9.63 a	4.60 a				
23					3.58	6.95 a	9.49 a	4.53 a				
24					3.43	6.95 a		4.37 a				
25					3.19			3.97 a				
26					3.02			3.78 a				
27					2.90			3.81 a				
28					2.76			3.67 a				
29					2.75			3.68 a				
30					2.75			3.50 a				
31					2.63			3.48 a				
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Jackfish Creek above confluence Athabasca River, station 07DD009

Latitude 58° 24' 45" N. Longitude 110° 50' 15" W. Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1971 to the present (seasonal operation in 1971) water sediment data also collected in 1971.

Location of Station Measurement section - located approximately one-third mile upstream from confluence Athabasca River.

Description of Equipment

Remarks Stage-discharge relationship defined by stage record at Richardson Lake at the outlet and Athabasca River above Jackfish Creek.

BENCH MARKS

STATION EQUIPMENT

LOCATION PLAN

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 3	0.24	2.62	352
Jun 16	2.76	5.02	7,320 ●
Jul 8	0.91	6.70	2,450 ●
Jul 20	3.27		13,400
Aug 5	1.40	6.02	4,050
Aug 19	0.60	4.51	1,240
Sep 1			0
Sep 30			0

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 2	1.01		2,508
Jun 22	4.76		5,022
Jul 5	1.07		3,853
Jul 18	.80		2,250
Aug 24	.85		1,678

● Flow into Richardson Lake from the Athabasca River

DESCRIPTION OF HYDROMETRIC STATION

Station Name Baril Lake at Center of Lake - Station No. 07KF005

Latitude 58° 46' 00" Longitude 111° 40' 00" . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1971 to present (seasonal)

Location of Station Twenty and one-half miles north 80° west of Fort Chipewyan. Gauge located in the center of Baril Lake.

Description of Equipment F-type recorder activated by a float. Staff gauge located in center of Lake. Sediment data collected in 1971.

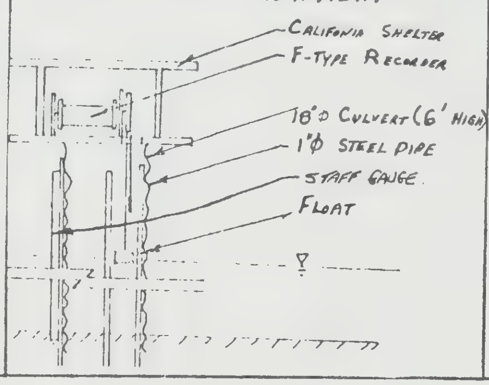
Remarks This station operated for the Peace-Athabasca Delta Study.

LOCATION PLAN

BENCH MARKS

BM 26 - Elevation 688.92 is C.E.S. bench mark on south shore of Baril Lake
BM 27 - Elevation 688.82 is C.E.S. bench mark on west shore of Baril Lake
BM 28 - Elevation 688.82 is C.E.S. bench mark on east shore of Baril Lake

STATION EQUIPMENT



BARIL LAKE AT CENTRE OF LAKE - STATION NO. 07KF005

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	686.18	686.84	686.46	686.38	---	---	1
2	---	---	---	---	---	---	686.21	686.80	686.51	686.40	---	---	2
3	---	---	---	---	---	---	686.22	686.80	686.51	686.40	---	---	3
4	---	---	---	---	---	---	686.25	686.80	686.51	686.41	---	---	4
5	---	---	---	---	---	---	686.28	686.74	686.52	686.39	---	---	5
6	---	---	---	---	---	---	686.35	686.74	686.53	686.43	---	---	6
7	---	---	---	---	---	---	686.41	686.72	686.52	686.45	---	---	7
8	---	---	---	---	---	---	686.31	686.75	686.51	686.37	---	---	8
9	---	---	---	---	---	---	686.29	686.72	686.49	686.43	---	---	9
10	---	---	---	---	---	---	686.27	686.69	686.47	686.37	---	---	10
11	---	---	---	---	---	---	686.26	686.74	686.50	686.36	---	---	11
12	---	---	---	---	---	---	686.25	686.69	686.50	686.40	---	---	12
13	---	---	---	---	---	---	686.29	686.63	686.56	686.45	---	---	13
14	---	---	---	---	---	---	686.29	686.63	686.56	686.39	---	---	14
15	---	---	---	---	---	---	686.28	686.66	686.53	686.35	---	---	15
16	---	---	---	---	---	---	686.35	686.61	686.48	586.29	---	---	16
17	---	---	---	---	---	---	686.47	686.62	686.42	686.29	---	---	17
18	---	---	---	---	---	---	686.53	686.60	686.52	686.34	---	---	18
19	---	---	---	---	---	---	686.65	686.58	686.55	686.34	---	---	19
20	---	---	---	---	---	---	686.80	686.57	686.44	686.35	---	---	20
21	---	---	---	---	---	---	686.86	686.55	686.45	686.34	---	---	21
22	---	---	---	---	---	685.82A	686.89	686.56	686.44	686.31	---	---	22
23	---	---	---	---	---	---	686.96	686.54	686.44	686.34A	---	---	23
24	---	---	---	---	---	---	686.99	686.52	686.43	---	---	---	24
25	---	---	---	---	---	---	687.00	686.50	686.43	---	---	---	25
26	---	---	---	---	---	---	686.91	686.50	686.44	---	---	---	26
27	---	---	---	---	---	---	686.98	686.50	686.46	---	---	---	27
28	---	---	---	---	---	686.20A	686.95	686.48	686.49	---	---	---	28
29	---		---	---	---	686.20	686.94	686.45	686.45	---	---	---	29
30	---		---	---	685.98A	686.17	686.98	686.43	686.38	---	---	---	30
31	---		---		---		686.86	686.44		---		---	31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 46 00 N
LONG 111 41 00 W

A-MANUAL GAUGE

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Birch River Below Alice Creek - Station No. 07KE001

Latitude 58° 19' N Longitude 113° 04' W S.W. Sec 26 Twp 107 Rge 19 W4

Established 1967
Re-established
Re-established

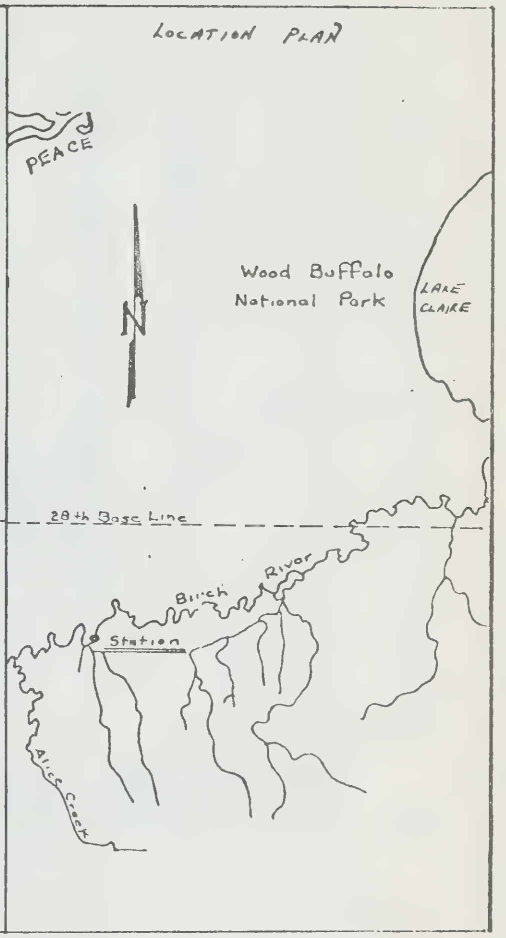
Observer

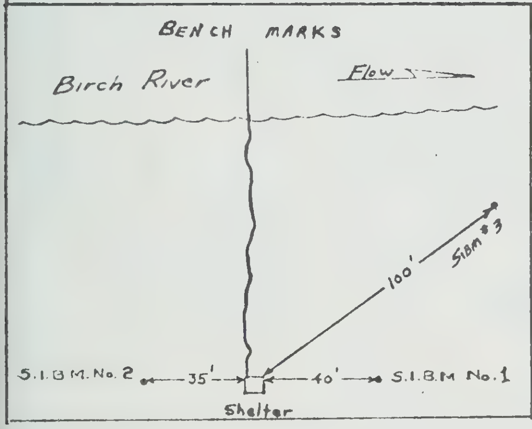
Period of Observation July 1967 to present

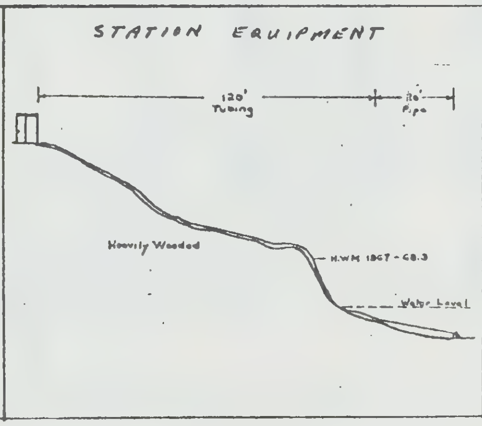
Location of Station About seventy-six air miles southwest of Fort Chipewyan or six miles below confluence with Alice Creek

Description of Equipment Recorder activated by a bubbler and also sediment data since 1970

Remarks







BIRCH RIVER BELOW ALICE CREEK - STATION NO. 07KE001

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	19.5 B	17.8 B	13.1 B	14.3 B	3000	1560	583	366	174	720	231 B	49.0 B	1
2	19.0 B	17.8 B	12.9 B	14.5 B	3120	1440	621	342	173	690	228 B	46.0 B	2
3	18.0 B	17.8 B	12.7 B	14.6 B	3150	1410	699	322	172	651	225 B	44.0 B	3
4	17.0 B	17.9 B	12.5 B	14.7 B	3080	1290	711	300	170	627	222 B	41.0 B	4
5	16.0 B	17.9 B	12.3 B	14.8 B	3030	1210	690	282	169	621	213 B	39.0 B	5
6	16.5 B	17.7 B	12.1 B	14.9 B	3000	1130	693	264	168	630	207 B	36.0 B	6
7	16.5 B	17.5 B	11.9 B	15.5 B	2920	993	714	242	166	618	195 B	35.0 B	7
8	16.6 B	17.3 B	11.7 B	15.0 B	2810	912	717	236	165	598	191 B	34.0 B	8
9	16.6 B	17.1 B	11.5 B	14.0 B	2720	898	687	224	164	575	186 B	33.0 B	9
10	16.7 B	16.9 B	11.6 B	14.5 B	2650	919	639	215	162	555	176 B	32.0 B	10
11	16.7 B	16.7 B	11.7 B	15.5 B	2520	937	598	203	161	535	162 B	31.0 B	11
12	16.8 B	16.5 B	11.8 B	16.5 B	2350	965	555	202	160	500	147 B	30.0 B	12
13	16.8 B	16.3 B	11.9 B	17.0 B	2170	989	518	201	158	475	131 B	29.5 B	13
14	16.9 B	16.1 B	12.0 B	17.5 B	1980	968	475	199	157	455	118 B	29.0 B	14
15	16.9 B	15.9 B	12.2 B	18.0 B	1930	923	435	198	161	448	113 B	28.5 B	15
16	17.0 B	15.7 B	12.3 B	18.5 B	1900	905	410	197	167	430	106 B	28.0 B	16
17	17.0 B	15.5 B	12.4 B	28.0 B	1830	958	392	195	191	415	102 B	27.5 B	17
18	17.1 B	15.3 B	12.5 B	62.0 B	1770	958	374	194	204	380	96.0 B	27.0 B	18
19	17.1 B	15.1 B	12.6 B	221 B	1720	898	350	193	216	380	93.0 B	27.0 B	19
20	17.2 B	14.9 B	12.7 B	735 B	1680	834	326	191	236	370	92.0 B	26.5 B	20
21	17.2 B	14.7 B	12.8 B	810 B	1710	774	302	190	262	366	91.0 B	26.0 B	21
22	17.3 B	14.5 B	12.9 B	1040 B	1760	724	282	189	266	358	87.0 B	26.0 B	22
23	17.3 B	14.3 B	13.1 B	1370 B	1770	687	264	187	278	354	81.0 B	26.0 B	23
24	17.4 B	14.1 B	13.2 B	1500 B	1770	654	246	186	306	346	78.0 B	25.5 B	24
25	17.4 B	13.9 B	13.3 B	1630 B	1760	633	262	185	394	346	73.0 B	25.0 B	25
26	17.5 B	13.7 B	13.4 B	1880 B	1760	639	312	183	533	344	69.0 B	25.0 B	26
27	17.5 B	13.5 B	13.6 B	2100 B	1750	621	418	181	593	342	63.0 B	24.5 B	27
28	17.6 B	13.3 B	13.7 B	2730	1730	588	440	180	687	314 B	59.0 B	24.5 B	28
29	17.6 B		13.9 B	2750	1730	568	415	178	738	240 B	55.0 B	24.0 B	29
30	17.7 B		14.1 B	2880	1720	565	405	177	741	237 B	52.0 B	23.5 B	30
31	17.7 B		14.2 B		1670		382	176		234 B		23.0 B	31
TOTAL	534.1	445.7	392.6	19985.8	68460	27550	14915	6778	8292	14154	3942.0	946.0	TOTAL
MEAN	17.2	15.9	12.7	666	2210	918	481	219	276	457	131	30.5	MEAN
AC-FT	1060	884	779	39600	136000	54600	29600	13400	16400	28100	7820	1880	AC-FT
MAX	19.5	17.9	14.2	2880	3150	1560	717	366	741	720	231	49.0	MAX
MIN	16.0	13.3	11.5	14.0	1670	565	246	176	157	234	52.0	23.0	MIN

SUMMARY FOR THE YEAR 1970

MEAN DISCHARGE, 456 CFS
TOTAL DISCHARGE, 330000 AC-FT
MAXIMUM DAILY DISCHARGE, 3150 CFS ON MAY 3
MINIMUM DAILY DISCHARGE, 11.5 CFS ON MAR 9

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 18 40 N
LONG 113 04 05 W

B-ICE CONDITIONS

NATURAL FLOW

BIRCH RIVER BELOW ALICE CREEK - STATION NO. 07KE001

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	22.0 B	21.0 B	8.8 B	5.8 B	2890	289	1650	269	296	1640	573 B	264 B	1
2	21.5 B	21.0 B	8.8 B	6.4 B	2650	281	1670	251	319	1580	539 B	262 B	2
3	21.0 B	20.5 B	8.5 B	6.0 B	2450	291	1750	246	573	1540	527 B	264 B	3
4	19.5 B	20.5 B	8.2 B	5.6 B	2230	309	1760	219	777	1440	521 B	260 B	4
5	19.0 B	20.0 B	8.2 B	5.2 B	2070	306	1730	211	780	1440	521 B	253 B	5
6	18.5 B	19.0 B	8.2 B	5.0 B	1930	301	1650	192	796	1340	521 B	239 B	6
7	18.5 B	19.0 B	7.9 B	6.2 B	1780	291	1540	182	735	1280	512 B	224 B	7
8	18.0 B	18.5 B	7.9 B	7.6 B	1660	281	1410	180	1020	1240	509 B	217 B	8
9	17.6 B	18.0 B	7.9 B	8.5 B	1530	272	1290	176	1060	1180	446 B	204 B	9
10	17.2 B	17.6 B	7.6 B	9.4 B	1390	262	1190	174	1100	1100	403 B	190 B	10
11	17.2 B	17.6 B	7.3 B	9.1 B	1270	255	1090	172	1100	1080	364 B	178 B	11
12	16.8 B	16.8 B	7.3 B	7.3 B	1170	248	989	163	1120	1050	353 B	170 B	12
13	16.8 B	16.8 B	7.3 B	6.6 B	1070	239	919	152	1080	1040	361 B	163 B	13
14	16.8 B	16.4 B	7.0 B	6.4 B	977	235	882	143	1020	1020	361 B	161 B	14
15	16.4 B	14.8 B	7.3 B	7.3 B	895	235	849	152	1170	1000	359 B	153 B	15
16	16.4 B	14.0 B	7.6 B	10.4 B	826	228	800	153	1810	951	353 B	144 B	16
17	15.6 B	13.6 B	7.3 B	40.0 B	761	272	777	165	2350	955	348 B	135 B	17
18	15.6 B	12.4 B	7.3 B	100 B	703	633	783	178	2710	909	332 B	126 B	18
19	15.6 B	11.6 B	7.0 B	132 B	646	691	767	174	3010	909	321 B	117 B	19
20	15.6 B	11.6 B	6.8 B	340 B	595	951	700	178	3140	885	309 B	109 B	20
21	14.8 B	11.2 B	6.6 B	852 B	551	601	655	309	3130	882	294 B	104 B	21
22	14.8 B	10.0 B	6.2 B	1450 B	503	598	592	420	3000	869	286 B	99.0 B	22
23	14.4 B	9.7 B	6.4 B	2450 B	464	579	561	470	2800	833	284 B	94.0 B	23
24	14.8 B	9.4 B	6.6 B	3580	435	542	512	479	2600	829	281 B	89.0 B	24
25	14.4 B	9.4 B	6.4 B	4000	406	500	464	473	2380	833	276 B	84.0 B	25
26	14.4 B	9.4 B	6.8 B	3930	384	485	426	435	2160	723	274 B	79.0 B	26
27	18.0 B	9.1 B	6.8 B	3800	356	551	400	409	2000	617 B	269 B	74.0 B	27
28	20.0 B	8 3 B	6.6 B	3640	348	1110	378	378	1880	671 B	267 B	69.8 B	28
29	21.5 B		6.2 B	3430	334	1360	342	348	1810	697 B	267 B	67.4 B	29
30	21.5 B		6.0 B	3170	321	1440	319	327	1720	659 B	267 B	65.0 B	30
31	21.5 B		5.8 B		304		299	314		601 B		61.7 B	31
TOTAL	545.7	417.7	224.6	31026.8	33899	14636	29144	8092	49446	31793	11298	4719.9	TOTAL
MEAN	17.6	14.9	7.2	1030	1090	488	940	261	1650	1030	377	152	MEAN
AC-FT	1080	829	445	61500	67200	29000	57800	16100	98100	63100	22400	9360	AC-FT
MAX	22.0	21.0	8.8	4000	2890	1440	1760	479	3140	1640	573	264	MAX
MIN	14.4	8.8	5.8	5.0	304	228	299	143	296	601	267	61.7	MIN

SUMMARY FOR THE YEAR 1971

MEAN DISCHARGE, 590 CFS
TOTAL DISCHARGE, 427000 AC-FT
MAXIMUM DAILY DISCHARGE, 4000 CFS ON APR 25
MINIMUM DAILY DISCHARGE, 5.0 CFS ON APR 5

MAXIMUM INSTANTANEOUS DISCHARGE
4050 CFS AT 1200 MST ON APR 25

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 18 40 N
LONG 113 04 05 W
DRAINAGE AREA 3860 SQ MILES

B-ICE CONDITIONS

NATURAL FLOW

DESCRIPTION OF HYDROMETRIC STATION

Station Name Chenal Des Quatre Fourches at Quatre Fourches - Station 07KF001

Latitude 58° 38' 50" N Longitude 111° 17' 20" W. . Sec Twp Rge

Established 1960
Re-established 1970
Re-established 1971

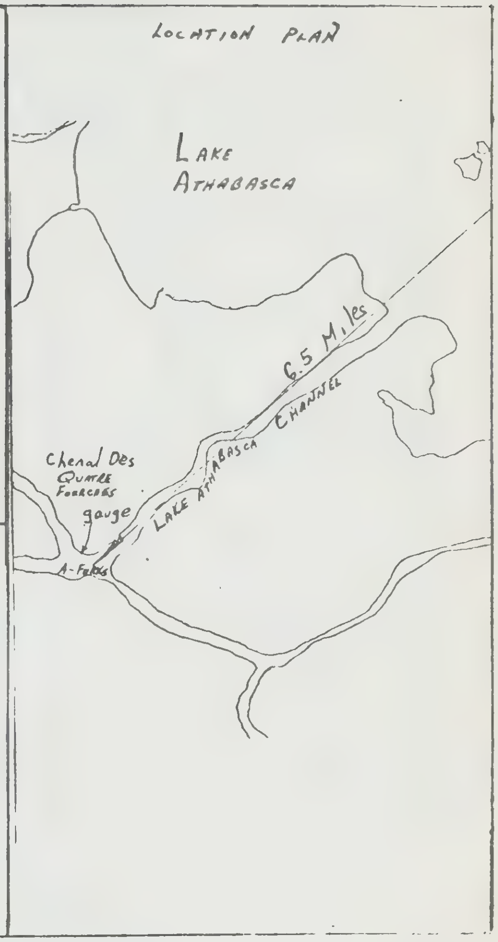
Observer

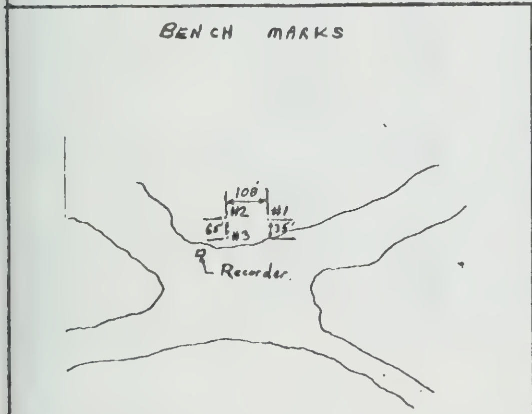
Period of Observation 1971 to present (recording gauge) manual gauge readings for 1960 and 1970.

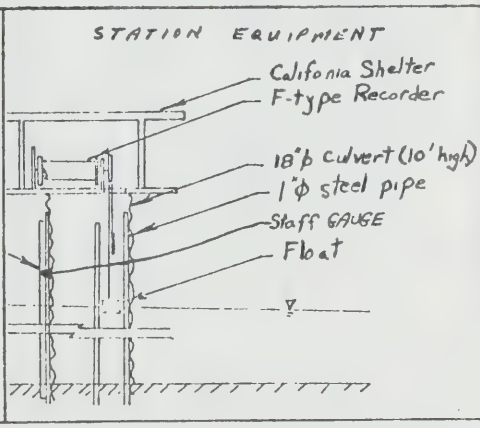
Location of Station Located on the north bank of Four Forks six and one-half miles southwest of Fort Chipewyan.

Description of Equipment F-type recorder activated by a float. Staff gauge located near north bank.

Remarks This station operated for the Peace-Athabasca Delta Study.







Chenal Des Quatre Fourches at Quatre Fourches - Station 07KF001
Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								683.63				
2							683.96	683.77				
3							683.88	683.98				
4							683.97	683.93				
5							683.90	684.03				
6							683.81	683.78				
7							683.85					
8							683.85	683.56				
9												
10							684.41					
11						684.40	684.60					
12						684.14		683.33				
13						684.44						
14						684.47		683.78				
15						684.54	684.07					
16						684.50	684.47	683.28				
17						684.33	684.42					
18						683.48	684.49	682.58				
19						683.70	684.15					
20						684.81	684.29	683.38				
21						684.16						
22						684.53	683.92	682.78				
23						684.50	683.69					
24						684.25	684.32	682.83				
25						683.55						
26						683.72	684.19					
27						684.28	684.15	683.26				
28							683.97					
29						685.39	684.05					
30							683.92					
31												
Mean												
Max												
Min												

Chenal Des Quatre Fourches at Quatre Fourches - Station 07KF001

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							684.92	686.18	684.97	683.05		
2							685.14	686.07	685.57	683.04		
3						684.10 a	685.47	685.99	684.99	683.04		
4						683.89 a	685.40	685.98	684.49	683.01		
5	687.04 a					684.31 a	685.54	686.12	684.60	683.01		
6						684.02 a	685.55	685.90	684.18	683.07		
7						683.77 a	685.62	685.92	684.04	682.35		
8						684.03 a	685.35	685.76	683.95	682.97		
9						683.94 a	685.31	685.79	683.95	682.50		
10						683.79 a	685.44	685.75	684.18	682.71		
11						683.77 a	685.34	685.72	684.08	683.08		
12							685.15	685.74	683.57	682.25		
13					684.88 a		685.28	685.21	682.92	683.37		
14							685.50	685.56	683.38	683.21		
15			677.97 a			684.74 a	686.17	685.89	684.24	683.01		
16						684.95 a	686.14	685.64	684.04	682.52		
17						684.57 a	686.27	685.49	683.15	682.47 a		
18						684.67 a	686.44	684.44	683.60	682.37 a		
19					684.10 a	684.47 a	686.46	685.40	683.65	682.39 a		
20						684.39 a	686.54	685.46	683.92	682.39 a		
21					684.34	684.74 a	686.64	685.40	683.53	682.27 a		
22					684.21	685.20 a	686.82	685.17	683.84	682.32 a		
23					684.02		687.27	684.94	684.02	682.25 a		
24					684.32		686.62	684.95	684.44	682.27 a		
25					684.10		686.43	684.96	684.71	681.95 a		
26					684.00	687.63 a	686.53	684.79	683.92			
27					684.03	685.57 a	686.43	684.96	683.34			
28					683.91	685.04 a	686.32	684.96	682.59			
29					684.12	685.04 a	686.14	684.82	682.94			
30					684.17	684.92	686.16	684.76	682.93			
31					683.84		686.16	684.82				
Mean							685.95	685.47	683.92			
Max							687.27	686.18	685.57			
Min							684.92	684.76	682.59			

Chenal Des Quatre Fourches at Quatre Fourches - Station 07KF001

Daily Elevations in Feet for the Year 1972

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						685.68	688.38		686.42	684.77		
2						686.08	688.32		686.34	684.72		
3						686.35	688.33	688.06 a	685.55	683.26		
4						685.95	688.36	688.21	686.24	684.10		
5						686.47	688.43	688.21	686.43	684.58		
6						686.32	688.46	688.00	686.20	684.22		
7						686.65	688.40	687.95	686.26	684.41		
8						687.22	688.40	687.93	686.17	684.53		
9						686.84	688.80	687.73	686.10	684.76		
10						686.68	689.48	687.54	685.86	684.11		
11						686.68	688.45	687.66	686.00	684.06		
12						686.48	688.25	687.92	685.89	683.90		
13						686.83	688.29	687.63	685.68	684.07		
14						686.82	688.13	687.51	686.34			
15						686.59	688.01	687.45	685.75			
16						686.71	688.30	687.31	686.10			
17						688.38	688.74	687.60	685.70			
18						688.10	688.67	687.62	685.81			
19						687.66	688.57	687.39	686.44			
20						687.59	688.56	687.38	686.24			
21						687.68	688.80	687.24	685.86			
22						687.99	688.82	687.27	686.24			
23						688.20	688.51	687.16	685.03			
24						688.15	688.78	687.81	684.24			
25						688.19	688.70	686.69	684.67			
26						688.08	688.19	686.54	684.71			
27						688.04	688.07	686.33	684.55			
28					686.73	688.04		686.86	684.51			
29					686.78	688.95		686.00	684.73			
30					686.54	688.93		686.69	684.85			
31					687.16			686.53				
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Chenal Des Quatre Fourches above Peace confluence - station 07KF004

Latitude 58° 52' 40" N. Longitude 111° 36' 10" W . Sec Twp Rge

Established 1960
Re-established 1970
Re-established 1971

Observer

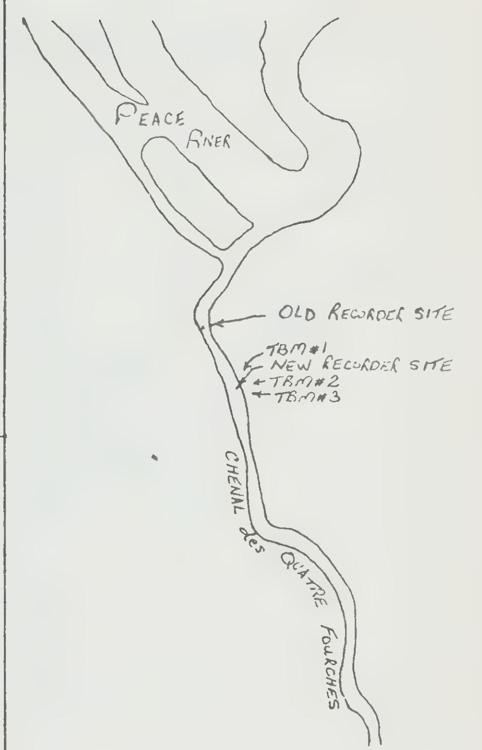
Period of Observation 1971 to present (recording-type gauge). Manual gauge recordings in 1960 and 1970.

Location of Station Twenty and one-half miles (air) northwest of Fort Chipewyan. Located one mile above the confluence with Peace River.

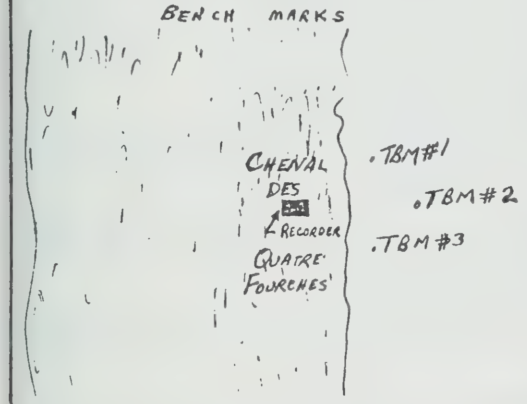
Description of Equipment A-35 float-type recorder.

Remarks This station operated for the Peace-Athabasca Delta Study.

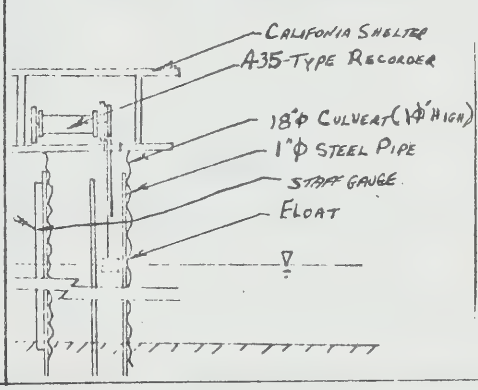
LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT



Chenal Des Quatre Fourches above Peace confluence - Station 07KF004

Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
								679.84				
1							682.39	679.87				
2							682.23	680.10				
3							682.08	680.40				
4							681.95	680.85				
5												
6							682.12	681.20				
7							682.47					
8							682.56	681.35				
9												
10							683.06	679.52				
11						684.93	683.01					
12						684.75		679.55				
13						684.65						
14						684.39		679.80				
15						684.10	682.14					
16						683.77		679.50				
17						683.77	681.94					
18						683.47		679.10				
19						683.06	681.33					
20						682.82		689.30				
21						682.75						
22						682.87	680.51	679.10				
23						682.97						
24						683.01	680.52	679.10				
25												
26						682.70	680.57					
27						682.91		678.96				
28												
29						683.39	680.35					
30							680.36					
31												
Mean												
Max												
Min												

Chenal Des Quatre Fourches above Peace confluence - Station 07KF004

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						682.53	684.97	684.22	681.24	679.96		
2						682.59	686.12	683.97	681.66	679.99		
3						682.68	687.28	683.69	681.43	680.14		
4						682.54	687.41	683.51	680.85	680.35		
5	678.58					682.71	687.10	683.39	680.72	680.46		
6						682.52	686.52	683.20	680.45	680.64		
7						682.23	685.94	683.00	680.24	680.14		
8						682.36	685.28	682.73	680.13	680.25		
9						682.46	684.95	682.48	680.17	680.11		
10						682.52	684.95	682.40	680.24	680.00		
11						682.69	684.90	682.30	680.45	680.40		
12						682.65	684.83	682.20	680.12	680.59		
13					683.95	682.85	685.31	681.84	679.84	681.25		
14						683.44	686.12	681.90	679.71			
15			677.70			684.25 a	686.79 a	682.25	680.31			
16							689.48 a	682.00	680.40	681.11		
17						684.84 a	690.33	681.82	680.12	680.79		
18								681.72	680.21	680.53		
19								681.67	680.26	680.31		
20					683.21		689.01	681.73	680.41	680.22		
21								681.75	680.39	679.94		
22								681.50	680.53	679.94		
23								681.14	680.71	679.82		
24								681.07	681.06	679.83		
25								681.07	681.27	679.45		
26								681.02	680.97	679.15 a		
27							685.36 a	681.12	680.34			
28							685.14	681.25	680.86			
29						684.80 a	684.59	681.15	679.79			
30						684.68	684.51	681.12	679.91			
31					682.51		684.30	681.10				
Mean								682.11	680.49			
Max								684.22	681.66			
Min								681.02	679.71			

Chenal Des Quatre Fourches above Peace confluence - Station 07KF004

Daily Elevations in Feet for the Year 1972

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							690.33					
2							690.31					
3							690.00					
4							689.60					
5							689.26					
6							688.90					
7							688.55					
8							688.20					
9							688.12					
10							688.36					
11							687.63					
12												
13												
14												
15												
16												
17						692.52						
18						692.88						
19						691.92						
20						690.82						
21						690.81						
22						690.81						
23						690.84						
24						690.50						
25						690.19						
26						690.27						
27						690.35						
28						690.35						
29						690.25						
30						690.13						
31												
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Chenal des Quatre Fourches below Four Forks, station 07KF006

Latitude 58° 39' 05" N. Longitude 111° 17' 50" W. . Sec Twp Rge

Established 1960
Re-established
Re-established

Observer

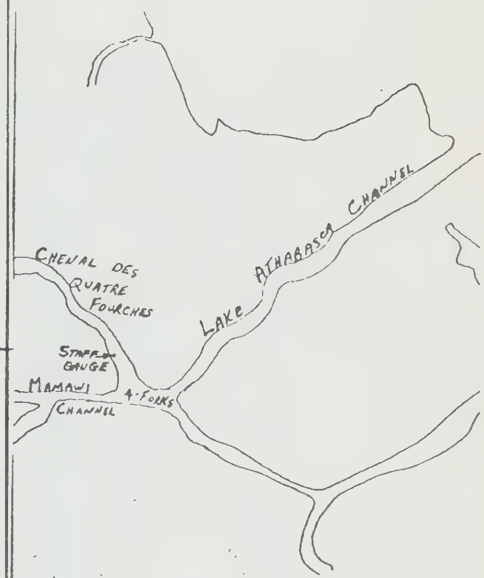
Period of Observation 1960, 1970 to present (seasonal) water sediment data collected in 1971.

Location of Station Approximately one'half mile north of Four Forks

Description of Equipment Staff gauge

Remarks This site used as a measuring section.

LOCATION PLAN



BENCH MARKS

BM 43 - Elevation 691.37 is C.E.S. bench mark on west side of channel about 1000 yards north of Four Forks

STATION EQUIPMENT

Chenal des Quatre Fourches below Four Forks - Station 07KF006

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2						684.00						
3						684.10			685.11			
4						684.00						
5								686.26				
6						684.12						
7												
8						684.18			684.07			
9									684.13			
10						683.87						
11						684.06		685.82				
12										682.06		
13												
14						684.63						
15						685.20						
16						684.96		685.68	684.08			
17						684.69						
18						684.74		685.49		681.91		
19							686.73					
20								685.51				
21						684.82	686.85		683.76			
22						685.31						
23												
24						685.51						
25						684.94						
26							686.53	684.74				
27							686.48					
28							686.45					
29						685.16	686.27		682.82			
30						684.96	686.22					
31							686.20					
Mean												
Max												
Min												

Chenal des Quatre Fourches below Four Forks -
Station No. 07KF006

Summary of Discharge Measurements

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs	Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 16	0.42	14.50	1,690				
Jun 17	0.60	14.33	2,400				
Jun 19	0.61	13.70	2,260				
Jun 23	1.41	14.50	5,680				
Jul 2	1.35	13.96	5,100				
Jul 10	1.32	14.41	5,110				
Jul 16	1.57	14.47	6,590				
Jul 18	1.77	14.49	7,370				
Jul 21	1.77	14.22	7,200				
Jul 23	1.86	13.69	6,940				
Jul 26	1.77	14.19	7,160				
Jul 27	1.84	14.15	7,110				
Jul 28	1.87	13.97	7,240				
Aug 6	1.54	13.78	5,620				
Aug 24	1.97	12.83	6,640				
Oct 30	1.67	11.06	3,930				

Chenal des Quatre Fourches below Four Forks

Station No. 07KF006

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs	Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jan 5	0.09		187 B	Aug 5	1.73	3.40	9,270
Mar 15			0 B	Aug 11	1.57	2.97	8,030
May 13	0.84		3,870	Aug 16	1.85	2.83	9,250
May 28	1.25	3.58	5,400	Aug 18	1.78	2.64	8,700
Jun 2	1.07	4.34	4,670	Aug 20	1.81	2.56	9,170
Jun 3	1.17	4.44	5,030	Aug 23	1.73	1.90	7,870
Jun 6	1.32	4.46	5,970	Sep 3	1.61	2.25	7,370
Jun 8	1.39	4.52	5,950	Sep 9	1.72	1.26	7,190
Jun 10	1.13	4.21	4,820	Sep 16	1.88	3.68	7,790
Jun 14	1.14	4.97	5,110	Sep 21	1.86	3.36	7,210
Jun 16	1.08	5.30	4,870 ●	Sep 24	1.77		7,650
Jun 18	0.94	5.08	4,220 ●	Sep 27	1.56	3.01	5,780
Jun 21	2.16	5.16	9,800 ●	Sep 29	1.63	5.22	5,670
Jun 23	3.00		16,000 ●	Oct 12	1.63	4.46	4,820
Jun 25	1.47	5.28	7,700 ●	Oct 18	1.17	4.31	3,360
Jun 28	1.31	5.49	6,380 ●				
Jun 30	0.57	5.30	2,740 ●				
Jul 2	1.68		8,240 ●				
Jul 5	1.94		9,580 ●				
Jul 12	0.42	4.70	2,020 ●				
Jul 14	1.39	5.31	6,630 ●				
Jul 16	2.46	5.87	13,100 ●				
Jul 19	2.52	686.76	14,200 ●				
Jul 21	1.91	3.96	10,600 ●				
Jul 26	0.55	3.65	2,880				
Jul 27	1.06	3.60	5,780				
Jul 30	1.14	3.35	6,020				

B Ice conditions

● Flow was southward toward Lake Athabasca

DESCRIPTION OF HYDROMETRIC STATION

Station Name Chenal des Quatre Fourches at Ranger's Cabin - station 07KF007

Latitude 58° 47' 40" N. Longitude 111° 28' 40" W. . Sec Twp Rge

Established 1970
Re-established
Re-established

Observer

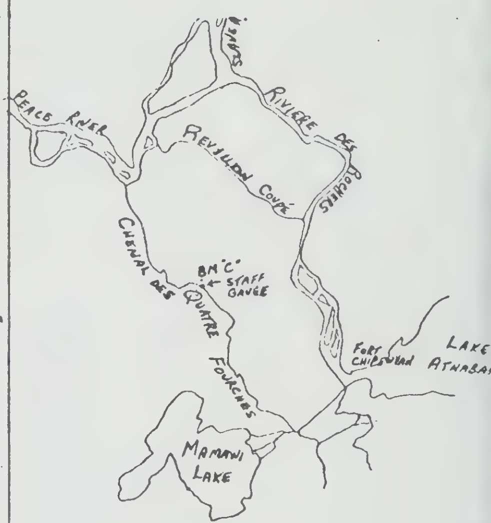
Period of Observation 1970 to present (seasonal)

Location of Station Approximately twelve miles above confluence with Peace River.

Description of Equipment Staff Gauge

Remarks Stage-type record only

LOCATION PLAN



BENCH MARKS

BM'C' - Elevation 691.69 is a brass plug (Topographic Survey of Canada) in rock outcrop on right bank.

STATION EQUIPMENT

Chenal des Quatre Fourches at Ranger's Cabin - Station 07KF007

Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
Mean						
Max						
Min						

	JUL	AUG	SEP	OCT	NOV	DEC
1		682.74				
2		683.09				
3		683.34				
4		683.29				
5		683.44				
6		683.34				
7						
8		683.34				
9						
10		681.04				
11						
12		682.69				
13						
14		682.94				
15						
16		682.64				
17						
18		681.84				
19						
20		682.64				
21						
22		682.14				
23						
24		682.14				
25						
26						
27		682.32				
28						
29	683.38					
30	683.19					
31						
Mean						
Max						
Min						

Chenal des Quatre Fourches at Ranger's Cabin - Station 07KF007

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2												
3												
4												
5												
6					684.80							
7												
8									682.98			
9									683.22			
10												
11						683.93		684.96				
12												
13												
14							686.23					
15												
16							688.45					
17						685.18						
18												
19							688.63	684.58				
20												
21									682.87			
22						687.81						
23												
24								683.96				
25												
26								683.87				
27							686.46					
28												
29						685.48						
30					684.08							
31							685.94	683.96				
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Chenal des Quatre Fourches at High Rock Tower, station 07KF008

Latitude 58° 48' 50" N. Longitude 111° 33' 30" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

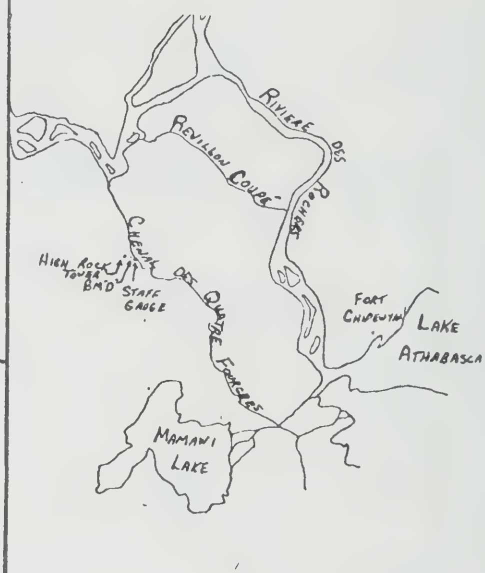
Period of Observation 1971 to present (seasonal)

Location of Station Approximately nine miles above confluence with Peace River, located directly below High Rock Tower.

Description of Equipment Staff gauge

Remarks Stage only type of record.

LOCATION PLAN



BENCH MARKS

BM'D' - Elevation 696.97 is 1/2" iron stove bolt on left bank in rock outcrop below fire lookout tower.

STATION EQUIPMENT

CHENAL des QUATRE FOURCHES AT HIGH ROCK TOWER - Station No. 07KF008

Daily Water Level in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						682.41	684.55	684.54				
2						682.39	685.58	684.39				
3						682.61	686.81	684.05				
4						682.41	686.96	684.05				
5						682.50	686.81	683.88				
6						682.50	686.20	683.81				
7						682.17	685.61	683.37				
8						682.28	685.18					
9						682.36			680.93			
10						682.37	684.64					
11						682.49	684.58					
12						682.57	684.52					
13						682.62	684.96					
14						682.91	685.70					
15						683.66	686.53					
16						684.29						
17						684.51						
18						684.56						
19						683.95	688.92					
20						683.72	688.60					
21							688.06					
22						688.26	687.28					
23						688.21	687.33					
24						687.92	686.24	681.82				
25						687.02						
26						687.68		680.69				
27						686.56						
28						685.17						
29						684.75						
30					682.54	684.52						
31												
							684.59	680.86				
Mean						684.12						
Max						688.26						
Min						682.17						

DESCRIPTION OF HYDROMETRIC STATION

Station Name Mamawi Lake Channel at Dog Camp, station 07KF010

Latitude 58° 38' 50" N. Longitude 111° 18' 40" W. . Sec Twp Rge

Established 1970
Re-established
Re-established

Observer

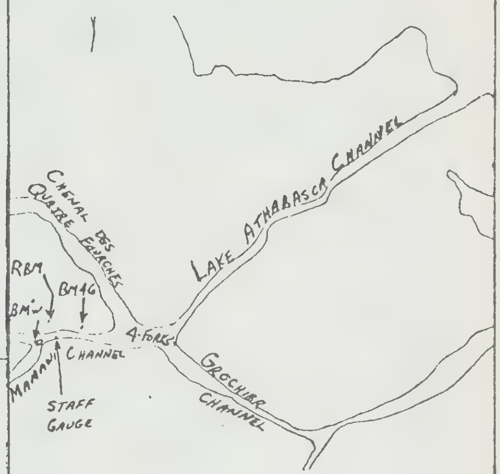
Period of Observation 1970 to present (seasonal), water sediment data collected in 1971.

Location of Station On south bank approximately one-half mile west of Four Forks.

Description of Equipment Staff gauge

Remarks This site used as a measuring section.

LOCATION PLAN



BENCH MARKS

BM'W' - Elevation 693.66 is brass cap on N.E. side of midstream bedrock outcrop which is now in the middle of dam constructed in 1971-1972
BM 46 - Elevation 688.64 is C.E.S. bench mark on north bank of Mamawi Channel about 1/4 mile west of Four Forks.
RBM - Elevation 691.92 is top of low rock about 500' in front of house at Dog Camp

STATION EQUIPMENT

Mamawi Lake Channel at Dog Camp - Station No. 07KF010

Daily Water Level in Feet for Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								683.56				
2												
3								683.96				
4												
5								683.96				
6								683.76				
7												
8								683.56				
9												
10												
11												
12								683.26				
13												
14								683.66				
15												
16								683.26				
17												
18								682.56				
19							684.09					
20								681.46				
21							684.21					
22							683.91	682.66				
23							683.76					
24							684.36	682.76				
25												
26							684.24					
27							684.11	683.17				
28							684.14					
29							684.08					
30							683.86					
31												
Mean												
Max												
Min												

Mamawi Lake Channel at Dog Camp - Station No.07KF010

Daily Water Levels in Feet for Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2						683.31						
3						684.09	685.55		684.90			
4						683.89						
5							685.42	686.06				
6					684.39							
7							685.61					
8						684.12						
9								685.85	683.96			
10						683.58	685.03					
11												
12							685.04			681.78		
13										683.54		
14						684.44	685.48					
15						685.01						
16						684.89	686.09		683.83			
17						684.51		685.48				
18								685.42		682.02		
19							686.43	685.42				
20								685.38				
21						684.56	686.92		683.60			
22												
23						685.89						
24						685.65			684.50			
25						685.21						
26							687.46					
27							686.32	684.89	683.27			
28						684.86						
29												
30						684.96	686.31					
31												
Mean												
Max												
Min												

Mamawi Lake Channel at Dog Camp - Station 07KF010

Summary of Discharge Measurements

1971

ate	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
ay 28	0.80	3.65	3,060
un 2	0.59	4.39	2,230
un 3		4.66	
un 8	0.46	4.70	1,770 ●
un 10	0.72	4.16	2,510
un 14	0.75	5.02	2,900
un 16	1.07	5.49	4,270 ●
un 23	2.37	6.48	10,700 ●
un 25	1.74	5.80	7,150 ●
un 28	1.46	5.44	5,950
un 30	0.48	5.51	2,010
ul 3	1.22	6.13	5,240 ●
ul 5	0.57	5.99	2,390 ●
ul 7	0.37	6.18	1,500
ul 12	0.92	5.60	3,750
ul 14	0.31	4.90	1,250
ul 16	1.25	5.51	5,600 ●
ul 19	0.79	5.82	3,610 ●
ul 21	2.03	6.34	9,530 ●
ul 26	1.12	6.87	5,080 ●
ul 27	0.78	5.72	3,550 ●
ul 30	0.69	5.71	3,130 ●
ug 5	1.10	5.45	4,920 ●
ug 9	0.39	5.24	1,710
ug 18	0.35	4.88	1,470
ug 19	0.85	4.89	3,420 ●
ug 24	1.31	2.27	5,200

1971 (Con't.)

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Sep 3	0.83	4.38	3,230
Sep 9	1.41	3.44	5,060
Sep 16	1.34	3.31	4,570
Sep 21	1.05	3.08	3,650
Sep 24	1.18	3.98	4,540 ●
Sep 27	1.54	2.75	5,130
Sep 29	1.32		4,330
Oct 12	1.58	5.89	4,290
Oct 18	1.05	6.13	2,970

● Flow was toward Mamawi Lake

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jul 11	.79	14.60	2,690
Jul 21	.49	14.21	1,770
Jul 23	.91	13.76	3,100
Jul 26	.66	14.24	2,310
Jul 28	.38	13.97	1,320
Aug 6	.21	13.76	725

DESCRIPTION OF HYDROMETRIC STATION

Station Name Lake Athabasca Channel East of Four Forks - station 07KF011

Latitude 58° 39' 10" N. Longitude 111° 16' 40" W. . Sec Twp Rge

Established 1970
Re-established
Re-established

Observer

Period of Observation 1970 to present

Location of Station On north bank approximately one mile northeast of Four Forks.

Description of Equipment Staff gauge

Remarks Miscellaneous discharge measurements taken at this site.

LOCATION PLAN

BENCH MARKS

STATION EQUIPMENT

Summary of Discharge Measurements

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jul 11	1.25	14.60	5,220
Jul 21	.99	14.21	4,480
Jul 23	.50	13.76	2,190
Jul 26	.68	14.24	3,030
Jul 28	1.34	14.14	6,080
Aug 6	1.25	13.76	5,580

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharg cfs
Mar 18	0.00		No Flow
Jun 14	1.75		8,220

DESCRIPTION OF HYDROMETRIC STATION

Station Name Grochier Channel Above Four Forks, station 07KF012

Latitude 58° 38' 35" N. Longitude 111° 16' 55" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1970 to the present

Location of Station On south bank approximately one-third mile south of Four Forks.

Description of Equipment Staff gauge

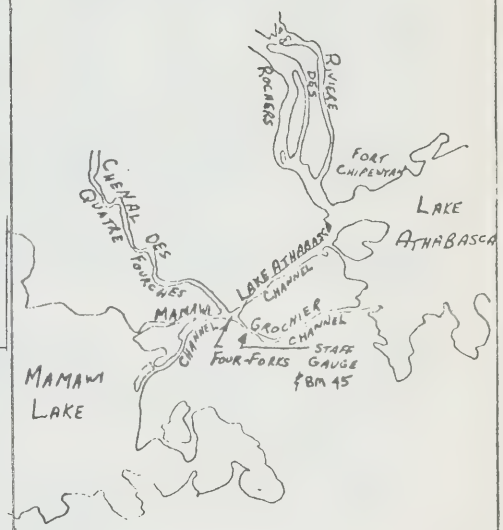
Remarks Miscellaneous discharge measurements taken at this site.

BENCH MARKS

BM 45 - Elevation 688.35 is C.E.S. bench mark located 20' from shoreline on south bank.

STATION EQUIPMENT

LOCATION PLAN



Summary of Discharge Measurements

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jul 11	.43	14.60	292
Jul 21	.70	14.21	541
Jul 23	.64	13.76	389
Jul 26	.73	14.24	468

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 8	0.91	5.78	555
Jun 14	1.31	6.02	916

DESCRIPTION OF HYDROMETRIC STATION

Station Name Lake Claire near outlet to Prairie River - Station No. 07KF002

Latitude 58° 38' 00" N. Longitude 111° 41' 50" . Sec 13 Twp 111 Rge 11 W4

Established 1970
Re-established
Re-established

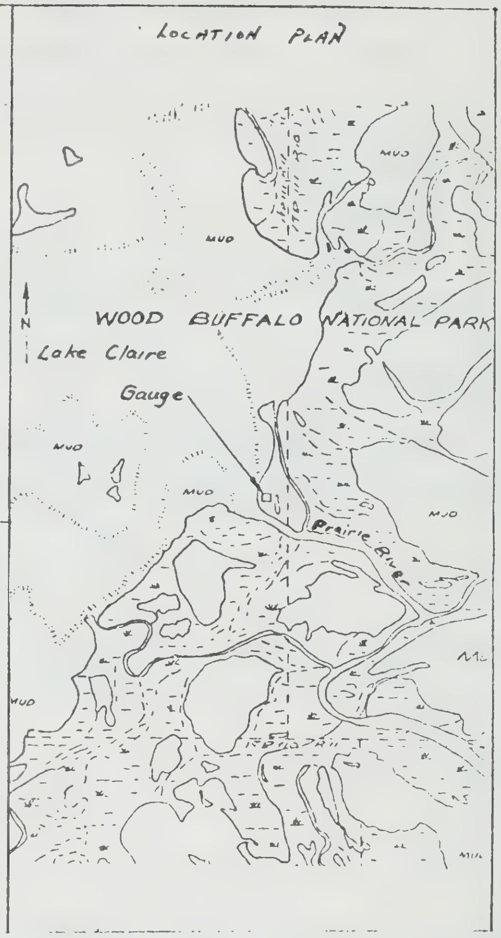
Observer

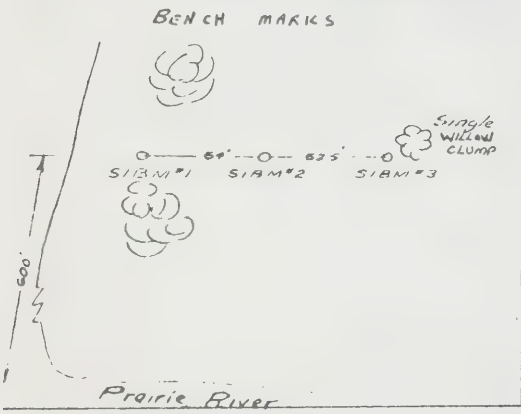
Period of Observation 1970 to present

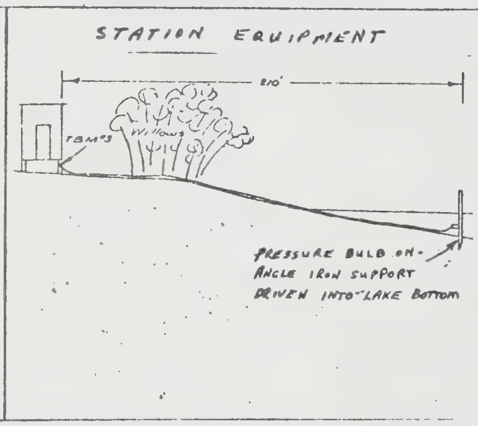
Location of Station On island near right bank of river, twenty-one miles west of Fort Chipewyan, by air.

Description of Equipment Recorder activated by pressure gauge

Remarks







LAKE CLAIRE NEAR OUTLET TO PRAIRIE RIVER - STATION NO. 07KF002

DAILY WATER LEVEL IN FEET FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	684.91	683.89	684.42	---	---	1
2	---	---	---	---	---	---	---	684.41	683.91	684.01	---	---	2
3	---	---	---	---	---	---	---	684.40	684.01	683.96	---	---	3
4	---	---	---	---	---	---	---	684.30	684.01	683.99	---	---	4
5	---	---	---	---	---	---	---	684.28	684.10	684.44	---	---	5
6	---	---	---	---	---	---	---	684.38	684.66	684.51	---	---	6
7	---	---	---	---	---	---	---	684.29	685.10	684.21	---	683.61	7
8	---	---	---	---	---	---	---	684.87	685.19	684.04	---	---	8
9	---	---	---	---	---	---	---	685.69	684.69	683.99	---	---	9
10	---	---	---	---	---	---	---	685.74	684.59	683.95	---	---	10
11	---	---	---	---	---	---	---	685.23	684.30	683.86	---	---	11
12	---	---	---	---	---	---	---	684.53	684.09	683.86	---	---	12
13	---	---	---	---	---	---	---	684.29	683.95	683.86	---	---	13
14	---	---	---	---	---	---	---	684.33	683.96	683.86	---	---	14
15	---	---	---	---	---	---	---	684.22	683.86	683.86	---	---	15
16	---	---	---	---	---	---	---	684.36	683.82	---	---	---	16
17	---	---	---	---	---	---	---	684.68	683.76	---	---	---	17
18	---	---	682.54	---	---	---	---	684.94	683.84	---	---	---	18
19	---	---	---	---	---	---	---	684.41	683.94	---	---	---	19
20	---	---	---	---	---	---	---	684.47	683.89	---	---	---	20
21	---	---	---	---	---	---	---	684.71	683.79	---	---	---	21
22	---	---	---	---	---	---	---	684.45	683.86	---	---	---	22
23	---	---	---	---	---	---	---	684.18	683.86	---	---	---	23
24	---	---	---	---	---	---	---	684.50	684.22	---	---	---	24
25	---	---	---	---	---	---	---	684.14	684.42	---	---	---	25
26	---	---	---	---	---	---	684.85	684.10	684.00	---	---	---	26
27	---	---	---	---	---	---	684.74	684.23	683.92	---	---	---	27
28	---	---	---	---	---	---	684.54	684.07	683.98	---	---	---	28
29	---		---	---	---	---	684.50	684.00	683.89	---	---	---	29
30	---		---	---	---	---	684.59	683.95	684.25	---	---	---	30
31	---		---		---		685.66	684.18		---		---	31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 38 00 N
LONG 111 42 00 W

NATURAL FLOW

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

LAKE CLAIRE NEAR OUTLET TO PRAIRIE RIVER - STATION NO. 07KF002

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	685.20	685.15	685.66	685.13	685.01	---	684.78	1
2	---	---	---	---	---	685.13	685.22	685.69	685.10	685.17	684.75A	684.80	2
3	---	---	---	---	---	685.10	685.22	685.88	685.40	685.22	684.73	684.80	3
4	683.50A	---	---	---	---	685.04	685.35	686.00	685.49	685.37	684.74	684.81	4
5	---	---	---	---	---	684.79	685.25	685.59	685.46	685.23	684.71	684.84	5
6	---	---	---	---	---	684.67	685.27	685.82	685.85	685.29	684.69	684.86	6
7	---	---	---	---	---	684.70	685.36	685.79	685.91	685.79	684.68	684.88	7
8	---	---	---	---	---	684.66	685.36	686.06	685.72	685.01	684.70	684.83	8
9	---	---	---	---	---	684.68	685.28	685.97	685.65	685.46	684.79	684.83	9
10	---	---	---	---	---	684.90	685.13	685.78	685.27	685.20	684.77	684.90	10
11	---	---	---	---	---	684.86	685.24	685.97	685.49	684.91	684.74	684.88	11
12	---	---	---	---	---	685.44	685.46	685.76	685.72	685.58	684.80	684.82	12
13	---	---	---	683.21A	---	684.90	685.59	685.96	686.38	684.76	684.78	684.80	13
14	---	---	---	---	---	684.69	685.55	685.55	686.52	684.88	684.79	---	14
15	---	683.38A	---	---	---	684.66	685.26	685.52	685.41	684.85	684.83	---	15
16	---	---	---	---	---	684.74	685.42	685.65	685.38	684.68	684.83	---	16
17	---	---	---	---	---	684.95	685.68	685.81	685.23	684.67	684.84	---	17
18	---	---	---	---	---	684.90	685.61	685.68	685.57	684.91	684.79	---	18
19	---	---	---	---	---	684.79	685.58	685.51	685.68	685.01	684.77	---	19
20	---	---	---	---	685.21A	684.85	685.65	685.54	685.17	685.01	684.76	---	20
21	---	---	---	---	684.92	684.87	685.60	685.68	685.25	685.04	684.76	---	21
22	---	---	---	---	685.10	684.82	685.55	685.97	685.13	684.74	684.82	---	22
23	---	---	---	---	685.37	684.90	685.57	686.01	684.93	684.87A	684.87	---	23
24	---	---	---	---	684.97	684.97	685.78	685.89	684.70	---	684.79	---	24
25	---	---	---	---	685.26	685.05	685.71	685.70	684.84	---	684.77	---	25
26	---	---	---	---	685.22	685.24	685.74	685.94	685.08	---	684.85	---	26
27	---	---	---	---	685.04	685.41	685.63	685.59	685.49	---	684.90	---	27
28	---	---	---	---	685.14	685.33	685.65	685.46	685.95	---	684.82	---	28
29	---		---	---	684.96	685.17	685.78	685.50	685.54	---	684.78	---	29
30	---		---	---	684.95	685.17	686.02	685.37	685.09	685.00A	684.77	---	30
31	---		---		685.04		685.72	685.29		---		---	31

A-MANUAL GAUGE

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 38 00 N
LONG 111 41 50 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Mamawi Lake at Poplar Island - Station 07KF003

Latitude 58° 36' 15" N. Longitude 111° 22' 00" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1971 to present (seasonal)

Location of Station Four and one-half miles by boat southwest of Four Forks, located on east shore of Mamawi Lake in the Mamawi Channel by Poplar Island.

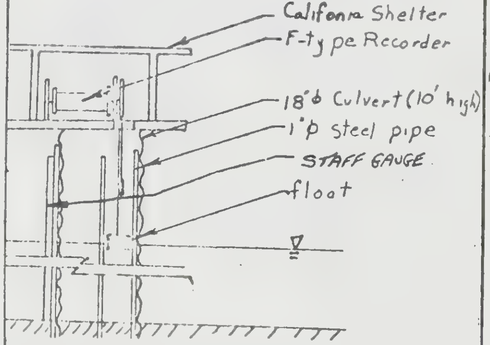
Description of Equipment F-type recorder activated by a float. Staff gauge located near east bank.

Remarks This station operated for the Peace-Athabasca Delta Study.

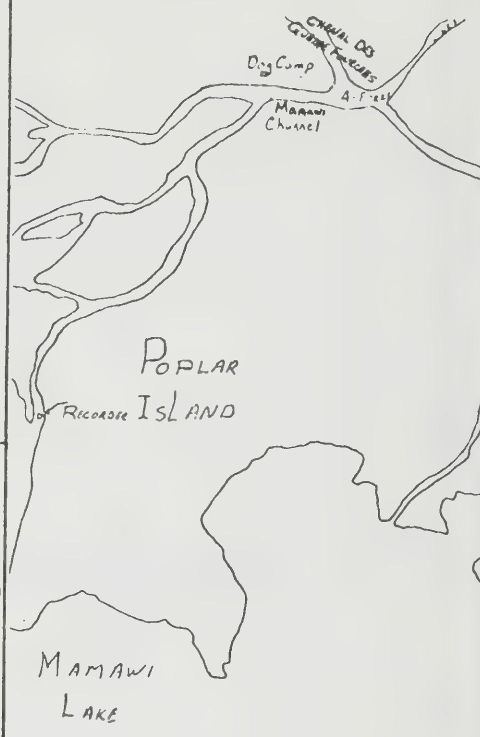
BENCH MARKS

TBM #1 - Nail in stake about 50 feet east of channel elevation 688.72 (September/71)

STATION EQUIPMENT



LOCATION PLAN



MAMAWI LAKE AT POPLAR ISLAND - STATION NO. 07KF003

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	684.03	685.00	685.84	684.78	683.17	---	---	1
2	---	---	---	---	---	683.90	685.15	685.78	684.96	683.29	---	---	2
3	---	---	---	---	---	683.95	685.39	---	685.03E	683.36	---	---	3
4	---	---	---	---	---	683.95	685.51	---	684.74A	683.51	---	---	4
5	---	---	---	---	---	684.02	685.49	---	684.73	683.38	---	---	5
6	---	---	---	---	---	683.89	685.52	---	684.68	683.49	---	---	6
7	---	---	---	---	---	683.76	685.47	---	684.62	683.87	---	---	7
8	---	---	---	---	---	683.84	685.25	---	684.48	683.28	---	---	8
9	---	---	---	---	---	683.84	685.08	685.70A	684.47	683.50	---	---	9
10	---	---	---	---	---	683.82	685.01	---	684.31	683.40	---	---	10
11	---	---	---	---	---	683.82	685.10	685.72A	684.41	683.22	---	---	11
12	---	---	---	---	---	683.85	685.09	685.63	684.24	683.42	---	---	12
13	---	---	---	---	---	683.80	685.24	685.38	684.52	683.52	---	---	13
14	---	---	---	---	---	683.89	685.31	685.25	684.62A	683.59	---	---	14
15	---	---	---	---	---	684.19	685.39	685.48	---	683.23	---	---	15
16	---	---	---	---	---	684.46	685.60	685.39	684.36A	682.57	---	---	16
17	---	---	---	---	---	684.57	685.89	685.43	683.62	682.35	---	---	17
18	---	---	---	---	---	684.45	686.05	685.34	684.12	682.43	---	---	18
19	---	---	---	---	---	684.39	686.08	685.23	684.32	682.65	---	---	19
20	---	---	---	---	---	684.31	686.23	685.19	684.15	682.88	---	---	20
21	---	---	---	---	683.90A	684.45	686.24	685.27	683.87	682.63	---	---	21
22	---	---	---	---	684.05	684.64	686.21	685.33	683.96	682.44	---	---	22
23	---	---	---	---	684.03	684.76	686.41	685.16	684.02	682.47	---	---	23
24	---	---	---	---	684.03	685.02	686.38	685.12	684.07	682.52	---	---	24
25	---	---	---	---	684.11	685.05	686.17	685.03	684.26	682.87A	---	---	25
26	---	---	---	---	684.33	685.34	686.11	685.00	684.26	---	---	---	26
27	---	---	---	---	684.25	686.09	686.10	684.99	684.14	---	---	---	27
28	---	---	---	---	684.25	685.59	685.99	684.97	684.23	---	---	---	28
29	---		---	---	684.10	685.23	685.91	684.88	683.98	---	---	---	29
30	---		---	---	684.09	685.09	686.03	684.77	683.40	---	---	---	30
31	---		---		684.04		685.89	684.75		---		---	31

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 36 15 N
LONG 111 22 00 W

A-MANUAL GAUGE
E-ESTIMATED

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Peace River at Peace Point - Station No. 07KC001

Latitude 59° 06' 50" N. Longitude 112° 25' 35" W. SE Sec 35 Twp 116 Rge 15 W4

Established June 1959
Re-established
Re-established

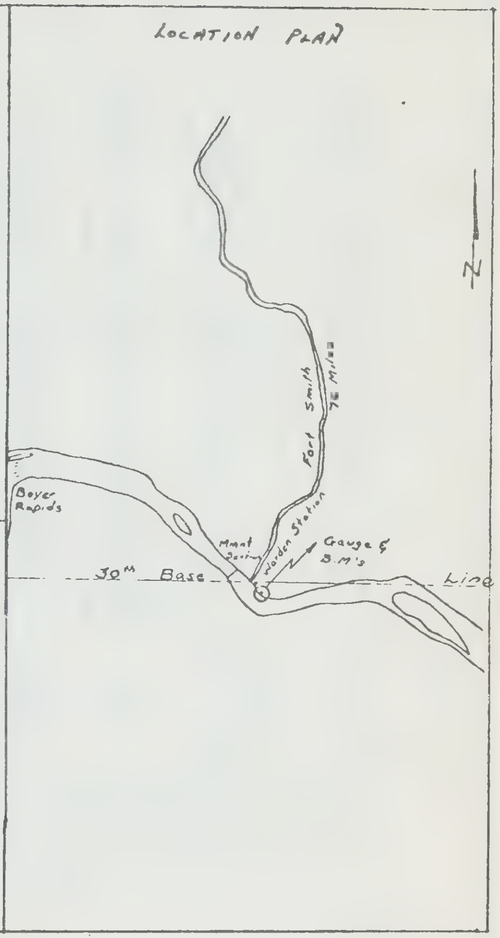
Observer

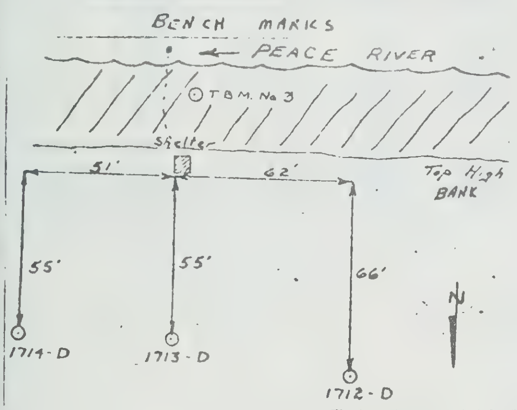
Period of Observation Continuous June 1959 to present

Location of Station One-half mile below Peace Point Park warden station on the left bank.

Description of Equipment Manual gauge 1959 to 1960; recording gauge with bubbler 1961 to present and sediment data collected 1967 to present

Remarks Regulated flow since 1968





STATION EQUIPMENT

PEACE RIVER AT PEACE POINT - STATION NO. 07KC001

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1970

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	29300 B	25800 B	24800 B	28800 B	64200 B	101000	72600	45400	31600	30700	40200	22600	1
2	29400 B	26000 B	25700 B	28900 B	65000 B	104000	71200	46500	32100	33000	40100	20800	2
3	29500 B	26500 B	26500 B	29500 B	66300 B	106000	69600	47400	32800	33900	39900	20000	3
4	29200 B	26900 B	26800 B	30400 B	70500 B	107000	68400	51300	32900	33900	39300	19800	4
5	28500 B	27000 B	26300 B	31700 B	76500 B	104000	70000	56500	32400	33400	38600	19400	5
6	27700 B	26800 B	25900 B	33200 B	79300	101000	75800	59600	31800	34700	38200	19000	6
7	26900 B	26200 B	26400 B	34200 B	76600	97300	83200	59200	31300	35400	37900	18900	7
8	27100 B	26400 B	27100 B	34200 B	75500	102000	86500	56400	31100	35100	37700	19100	8
9	28800 B	26500 B	27400 B	34100 B	74600	118000	85600	52700	30900	34800	37200	19100	9
10	30000 B	26700 B	27400 B	35200 B	75300	134000	82100	48600	31000	34600	37000	19200	10
11	31100 B	26300 B	27200 B	37400 B	76400	138000	78200	45200	31200	35100	34600	19300 B	11
12	32200 B	26000 B	26900 B	40000 B	77000	133000	75000	43500	31700	36300	31000	19700 B	12
13	32100 B	25600 B	26800 B	42500 B	77100	125000	71500	42700	31300	37700	31600	19800 B	13
14	31900 B	25200 B	26700 B	45200 B	76500	118000	67900	42000	30200	39100	35000 B	20100 B	14
15	31400 B	25000 B	26800 B	47400 B	75700	112000	65300	41400	29300	39900	36500 B	20500 B	15
16	30800 B	25200 B	27100 B	50000 B	75200	106000	62800	40500	29500	39700	37800 B	21300 B	16
17	30000 B	25900 B	27200 B	52800 B	77300	101000	60200	39300	30000	39200	38200 B	22800 B	17
18	29500 B	26300 B	26800 B	55000 B	83000	94800	57100	38300	30200	38700	38000 B	24100 B	18
19	28900 B	26900 B	26400 B	57300 B	87900	87200	53800	38500	30200	37500	36000 B	25300 B	19
20	28600 B	27200 B	26300 B	59000 B	88100	81200	50800	38800	30500	37400	34200 B	26900 B	20
21	28100 B	27600 B	26700 B	61000 B	86700	77500	49500	38900	30600	37800	32500 B	28000 B	21
22	27800 B	27700 B	26900 B	61900 B	86800	76900	48900	39500	30200	37900	31000 B	29200 B	22
23	27200 B	27700 B	27400 B	62500 B	94200	81100	48100	39100	29800	38100	29200 B	30200 B	23
24	27000 B	26500 B	27700 B	63000 B	103000	84500	47400	37800	29400	37500	28100 B	30900 B	24
25	26800 B	24900 B	27500 B	64000 B	106000	84900	47100	36700	30100	37000	27700 B	31200 B	25
26	26300 B	23700 B	27700 B	63800 B	102000	83000	47100	36200	30100	36900	27800 B	31400 B	26
27	25800 B	23700 B	27800 B	63600 B	98200	79600	46600	35800	29200	38100	28500 B	31300 B	27
28	25600 B	24200 B	28400 B	63600 B	96800	76300	46500	34900	29200	39300	28900 B	31100 B	28
29	25200 B		28900 B	63800 B	97600	75300	46500	33900	29700	39800	27500 B	30900 B	29
30	25300 B		29400 B	63900 B	99500	74700	46200	32900	29800	40300	25500 B	30400 B	30
31	25500 B		29200 B		99900		45400	32100		40300		30100 B	31
TOTAL	883500	730400	840100	1437900	2588700	2964300	1926900	1331600	920100	1143100	1025700	752400	TOTAL
MEAN	28500	26100	27100	47900	83500	98800	62200	43000	30700	36900	34200	24300	MEAN
AC-FT	1750000	1450000	1670000	2850000	5130000	5880000	3820000	2640000	1830000	2270000	2030000	1490000	AC-FT
MAX	32200	27700	29400	64000	106000	138000	86500	59600	32900	40300	40200	31400	MAX
MIN	25200	23700	24800	28800	64200	74700	45400	32100	29200	30700	25500	18900	MIN

SUMMARY FOR THE YEAR 1970

MEAN DISCHARGE, 45300 CFS
TOTAL DISCHARGE, 32800000 AC-FT
MAXIMUM DAILY DISCHARGE, 138000 CFS ON JUN 11
MINIMUM DAILY DISCHARGE, 18900 CFS ON DEC 7

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 06 50 N
LONG 112 25 35 W
DRAINAGE AREA 113000 SQ MILES

B-ICE CONDITIONS

NATURAL FLOW

PEACE RIVER AT PEACE POINT - STATION NO. 07KC001

DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	29800 B	27700 B	37400 B	35300 B	148000	74100	136000	71000	44200	46500	42100 B	39600 B	1
2	29600 B	27900 B	37100 B	35100 B	139000	74900	171000	67600	42700	48300	41800 B	38500 B	2
3	29500 B	28100 B	37000 B	35000 B	125000	74100	187000	65400	42600	51300	42700 B	36300 B	3
4	29800 B	28400 B	36600 B	35000 B	117000	72100	181000	62700	41800	54000	41600 B	35500 B	4
5	30100 B	28600 B	36200 B	34900 B	114000	68700	164000	60700	40900	55000	41200 B	35400 B	5
6	31000 B	28800 B	35900 B	34900 B	112000	67200	146000	58600	39900	54300	39500 B	35200 B	6
7	31500 B	29000 B	35500 B	34800 B	108000	66900	129000	56000	39300	52600	36000 B	34700 B	7
8	31600 B	29600 B	35100 B	34800 B	101000	67900	115000	53800	39600	51800	36900 B	34000 B	8
9	31300 B	30300 B	34800 B	34800 B	[illegible]	70500	107000	52400	40400	50500	38200 B	32800 B	9
10	31000 B	31000 B	34500 B	34700 B	92300	74100	104000	51500	41300	51600	39800 B	31600 B	10
11	30800 B	31600 B	34600 B	34700 B	89200	77200	106000	50400	41500	57500	39200 B	31900 B	11
12	30700 B	32100 B	34800 B	34600 B	87800	79300	116000	49500	41600	64000	38300 B	32100 B	12
13	30600 B	32500 B	35100 B	34800 B	85400	81200	139000	49400	40500	66200	37400 B	31500 B	13
14	29600 B	32900 B	35300 B	35100 B	82600	92400	152000	47800	39900	66300	36000 B	29800 B	14
15	29300 B	33000 B	35100 B	35500 B	81100	116000	167000	46800	41500	64900	36300 B	29500 B	15
16	29900 B	33100 B	34800 B	35900 B	77300	126000	240000	46200	43600	62200	37000 B	28100 B	16
17	30300 B	33200 B	34400 B	36200 B	73500	124000	276000	45800	45100	59100	37400 B	27600 B	17
18	30100 B	33300 B	34300 B	36500 B	72500	115000	264000	45800	44700	56100	37800 B	26900 B	18
19	29000 B	33400 B	34700 B	36800 B	77300	107000	233000	45900	45000	53900	38000 B	26200 B	19
20	26800 B	33600 B	35000 B	37000 B	85400	123000	202000	45900	46400	52500	37800 B	24200 B	20
21	24800 B	33900 B	35200 B	37300 B	89300	196000	177000	45400	47200	51700	37700 B	24200 B	21
22	24500 B	34500 B	35400 B	38100 B	83600	237000	155000	44400	47900	50900	37400 B	24100 B	22
23	24800 B	35000 B	35600 B	38600 B	78900	229000	137000	43500	48700	50500	37300 B	22800 B	23
24	25300 B	35700 B	35900 B	45000 B	72800	202000	121000	43100	47900	50200	37100 B	22600 B	24
25	25600 B	36300 B	36000 B	63600 B	68300	176000	107000	43900	46300	49300	38500 B	22500 B	25
26	25900 B	36800 B	36100 B	83000 B	65800	154000	97700	44900	45100	47500	39800 B	23800 B	26
27	26100 B	37000 B	36200 B	130000 B	64900	138000	91000	45400	45300	45800	38800 B	25000 B	27
28	26400 B	37100 B	36100 B	166000 B	65400	123000	85400	45500	45900	44200	38800 B	29800 B	28
29	26700 B		35900 B	165000 B	67500	114000	81200	45700	46500	42300	39800 B	31300 B	29
30	26900 B		35600 B	157000	69700	115000	76600	45700	46600	41300 B	39900 B	33200 B	30
31	27200 B		35500 B		72300		74700	45300		42700 B		33800 B	31
TOTAL	886500	904400	1101700	1630000	2763000	3435600	4538600	1566000	1309900	1635000	1160100	934500	TOTAL
MEAN	28600	32300	35500	54300	89100	115000	146000	50500	43700	52700	38700	30100	MEAN
AC-FT	1760000	1790000	2190000	3230000	5480000	6810000	9000000	3110000	2600000	3240000	2300000	1850000	AC-FT
MAX	31600	37100	37400	166000	148000	237000	276000	71000	48700	66300	42700	39600	MAX
MIN	24500	27700	34300	34600	64900	66900	74700	43100	39300	41300	36000	22500	MIN

SUMMARY FOR THE YEAR 1971

MEAN DISCHARGE, 59900 CFS
TOTAL DISCHARGE, 43400000 AC-FT
MAXIMUM DAILY DISCHARGE, 276000 CFS ON JUL 17
MINIMUM DAILY DISCHARGE, 22500 CFS ON DEC 25

MAXIMUM INSTANTANEOUS DISCHARGE
279000 CFS AT 1200 MST ON JUL 17

TYPE OF GAUGE - RECORDING
LOCATION - LAT 59 06 50 N
LONG 112 25 35 W
DRAINAGE AREA 113000 SQ MILES

B-ICE CONDITIONS

REGULATED SINCE 1968

DESCRIPTION OF HYDROMETRIC STATION

Station Name Peace River at Sweetgrass Landing, station 07KC004

Latitude 58° 55' 41" N. Longitude 111° 55' 00" W. · Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

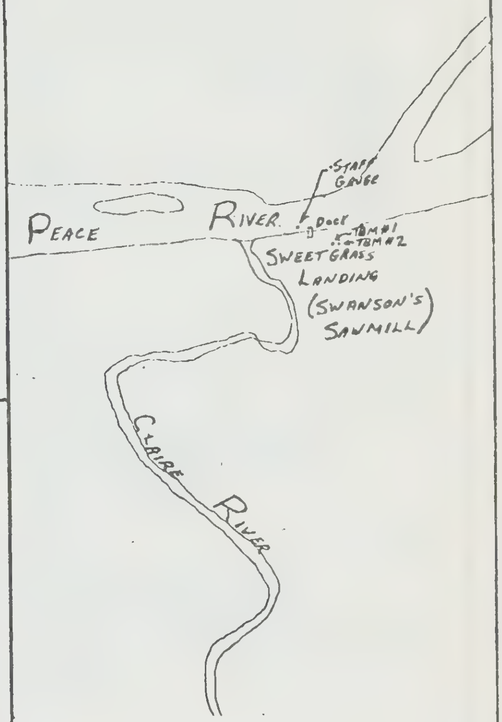
Period of Observation 1971 to the present (seasonal)

Location of Station At Swanson's Sawmill, Sweetgrass Landing, sixteen miles above Chenal des Quatre Fourches - Peace River confluence.

Description of Equipment Staff gauge

Remarks Stage type of record only

LOCATION PLAN



BENCH MARKS

TBM 1 - Elevation 100.00 (Assumed) nail in 14" diameter Birch tree 120 yards south of river

TBM 2 - Elevation 96.37 (Assumed) nail in 10" diameter Poplar tree 45' east of TBM 1

STATION EQUIPMENT

PEACE RIVER AT SWEETGRASS LANDING - STATION NO. 07KC004

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	5.58	---	5.40	---	---	---	---	1
2	---	---	---	---	---	4.67	10.37	5.12	---	---	---	---	2
3	---	---	---	---	---	4.70	11.47	---	---	---	---	---	3
4	---	---	---	---	---	4.73	11.57	---	---	---	---	---	4
5	---	---	---	---	---	4.47	10.99	---	---	---	---	---	5
6	---	---	---	---	---	4.33	9.87	---	---	---	---	---	6
7	---	---	---	---	---	4.09	---	---	---	---	---	---	7
8	---	---	---	---	---	4.25	---	---	---	---	---	---	8
9	---	---	---	---	---	4.33	7.64	---	---	---	---	---	9
10	---	---	---	---	---	4.45	7.33	---	---	---	---	---	10
11	---	---	---	---	---	4.76	7.53	---	---	---	---	---	11
12	---	---	---	---	---	5.02	7.45	---	---	---	---	---	12
13	---	---	---	---	---	4.84	---	---	---	---	---	---	13
14	---	---	---	---	---	5.35	9.65	---	---	---	---	---	14
15	---	---	---	---	---	5.95	10.31	---	---	---	---	---	15
16	---	---	---	---	---	---	13.93	---	---	---	---	---	16
17	---	---	---	---	---	---	14.61	---	---	---	---	---	17
18	---	---	---	---	---	7.86	15.09	---	---	---	---	---	18
19	---	---	---	---	---	7.18	13.89	---	---	---	---	---	19
20	---	---	---	---	---	6.97	12.93	---	---	---	---	---	20
21	---	---	---	---	---	---	11.97	---	---	---	---	---	21
22	---	---	---	---	---	---	10.99	---	---	---	---	---	22
23	---	---	---	---	---	13.39	10.35	---	---	---	---	---	23
24	---	---	---	---	---	12.88	---	---	---	---	---	---	24
25	---	---	---	---	---	11.58	---	---	---	---	---	---	25
26	---	---	---	---	---	11.38	7.63	---	---	---	---	---	26
27	---	---	---	---	---	10.77	7.35	---	---	---	---	---	27
28	---	---	---	---	---	10.39	7.10	---	---	---	---	---	28
29	---		---	---	---	9.77	6.74	---	---	---	---	---	29
30	---		---	---	---	---	6.30	---	---	---	---	---	30
31	---		---		4.49		5.62	---		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 55 41 N
LONG 111 55 00 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO ASSUMED DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Peace River at Carlson's Landing, station 07KC003

Latitude 58° 58' 40" N. Longitude 111° 48' 50" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

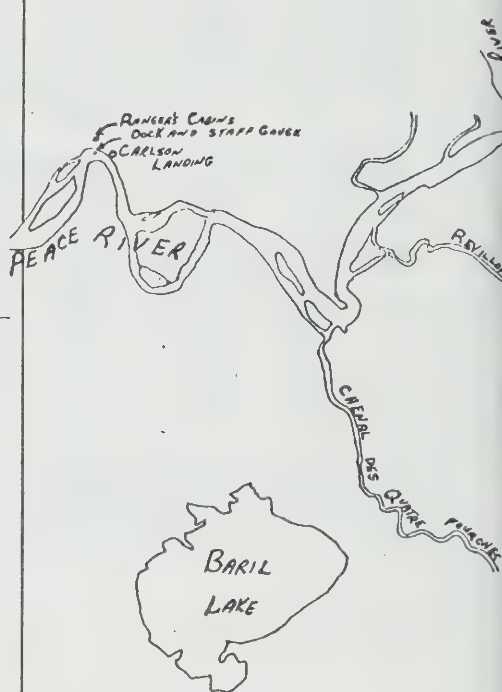
Period of Observation 1971 to the present (seasonal in 1971)

Location of Station On left bank, approximately ten miles above Chenal des Quatre Fourches - Peace River confluence

Description of Equipment Staff gauge

Remarks Stage-only type of record.

LOCATION PLAN



BENCH MARKS

BM 1704 D - Elevation 734.23 is iron pipe with brass cap on north side of Peace River and about 98 feet north of Forestry Cabin
BM 1703 D - Elevation 737.77 is east concrete foundation wall of Forestry Cabin

STATION EQUIPMENT

PEACE RIVER AT CARLSON LANDING - STATION NO. 07KC003

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	---	---	---	---	---	1
2	---	---	---	---	---	---	---	---	---	---	---	---	2
3	---	---	---	---	---	---	---	---	---	---	---	---	3
4	---	---	---	---	---	---	---	---	---	---	---	---	4
5	---	---	---	---	---	---	---	---	---	---	---	---	5
6	---	---	---	---	---	---	---	---	---	---	---	---	6
7	---	---	---	---	---	684.95	---	---	---	---	---	---	7
8	---	---	---	---	---	684.94	---	---	---	---	---	---	8
9	---	---	---	---	---	684.96	---	---	---	---	---	---	9
10	---	---	---	---	---	685.18	---	---	---	---	---	---	10
11	---	---	---	---	---	685.44	---	---	---	---	---	---	11
12	---	---	---	---	---	685.69	---	---	---	---	---	---	12
13	---	---	---	---	---	685.90	---	---	---	---	---	---	13
14	---	---	---	---	---	685.96	---	---	---	---	---	---	14
15	---	---	---	---	---	687.25	---	---	---	---	---	---	15
16	---	---	---	---	---	688.80	---	---	---	---	---	---	16
17	---	---	---	---	---	688.88	---	---	---	---	---	---	17
18	---	---	---	---	---	688.60	---	---	---	---	---	---	18
19	---	---	---	---	---	687.95	---	---	---	---	---	---	19
20	---	---	---	---	---	687.65	---	---	---	---	---	---	20
21	---	---	---	---	---	---	---	---	---	---	---	---	21
22	---	---	---	---	---	---	---	---	---	---	---	---	22
23	---	---	---	---	---	---	---	---	---	---	---	---	23
24	---	---	---	---	---	---	---	---	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	---	---	---	---	---	---	---	---	---	26
27	---	---	---	---	---	---	---	---	---	---	---	---	27
28	---	---	---	---	---	---	---	---	---	---	---	---	28
29	---		---	---	---	---	---	---	---	---	---	---	29
30	---		---	---	---	---	---	---	---	---	---	---	30
31	---		---		685.00		---	---		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 58 40 N
LONG 111 48 50 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Prairie River at Fish Study Camp, station 07KF013

Latitude 58° 37' 15" N. Longitude 111° 38' 10" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1971 to the present (seasonal in 1971)

Location of Station On south bank approximately half way between Lake Claire and Mamawi Lake.

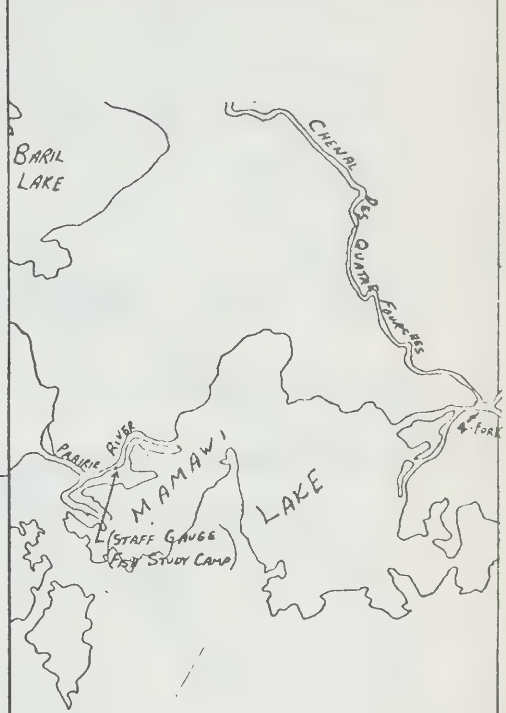
Description of Equipment Staff gauge

Remarks Stage-only type of record.

BENCH MARKS

STATION EQUIPMENT

LOCATION PLAN



Prairie River at Fish Study Camp - Station No. 07KF013

Daily Water Level in Feet for Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							2.00	2.78				
2							2.08	2.72				
3								2.78				
4							2.02	2.88				
5							2.10	2.66				
6							2.19	2.73				
7							2.25	2.63				
8							2.23	2.75				
9							2.18					
10												
11						2.60	2.10					
12						2.10	2.25					
13							2.33					
14						1.50	2.31					
15							2.25					
16							2.47					
17												
18							2.70					
19							2.80					
20							2.85					
21												
22												
23												
24												
25												
26							2.90					
27							2.93					
28							2.85					
29						2.00	2.85					
30						2.03	2.93					
31							2.80					
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Prairie River near outlet Lake Claire, station 07KF014

Latitude 58° 37' 25" N. Longitude 111° 40' 50" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

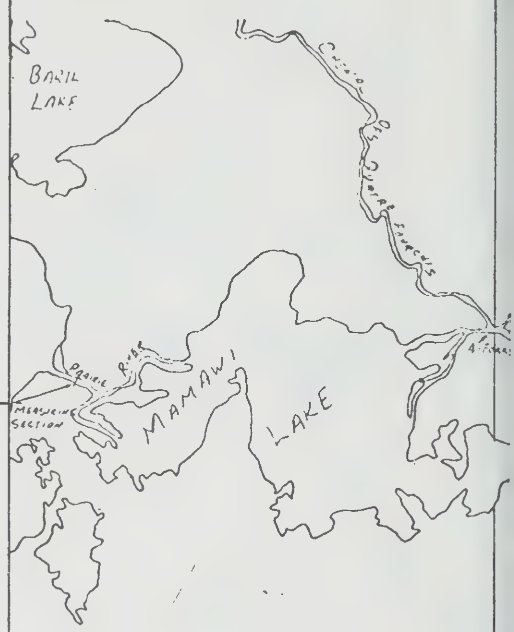
Period of Observation 1971 to the present (seasonal in 1971). Sediment data also collected in 1971.

Location of Station Measurement section - located on Prairie River approximately 3/4 mile east of Lake Claire.

Description of Equipment Used as measuring section only

Remarks Miscellaneous discharge measurements taken at this site.

LOCATION PLAN



BENCH MARKS

STATION EQUIPMENT

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jul 29	1.42	5.78	3,350 ●
Aug 4	0.97	1.58	2,410
Aug 9	1.05	4.86	2,520
Aug 17	1.20	4.72	2,880
Aug 19	1.07	4.28	2,530 ●
Aug 24	1.05	4.67	2,490
Aug 31		4.18	0
Sep 20	1.17	2.25	2,580

● Flow was toward Lake Claire

DESCRIPTION OF HYDROMETRIC STATION

Station Name Revillon Coupe below confluence Riviere des Rochers, station 07NA004

Latitude 58° 51' 10" N. Longitude 111° 16' 10" W . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

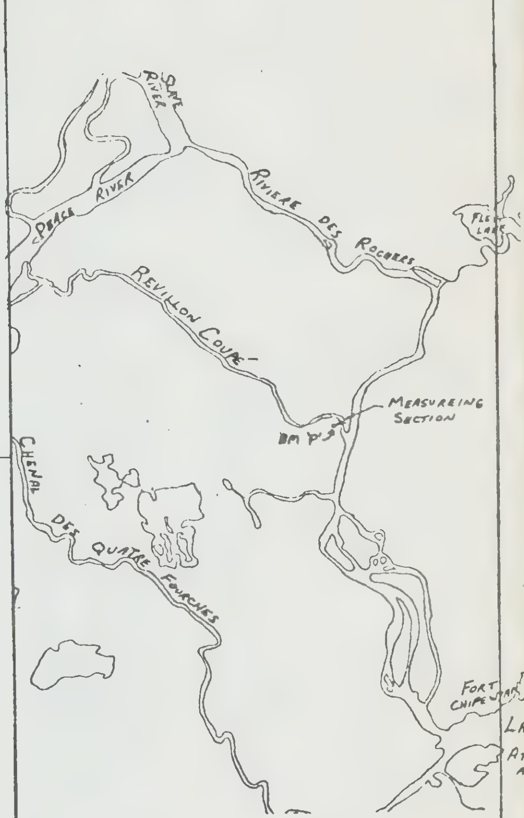
Period of Observation 1970 to the present (seasonal) water sediment data also collected in 1971.

Location of Station Measuring section-located approximately one-quarter mile below confluence with Riviere des Rochers.

Description of Equipment Staff gauge in 1970.

Remarks Stage-discharge relationship by staff gauge at Riviere des Rochers above confluence Revillon Coupe.

LOCATION PLAN



BENCH MARKS

BM 'P' - Elevation 692.49 is twisted iron bar in concrete south of yellow blazed tree about 35' from left bank.

STATION EQUIPMENT

Revillon Coupe Below Confluence Riviere des Rochers - Station No. 07NA004

Daily Water Levels in Feet for Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								682.32			679.68	
2							682.87	682.47				
3							682.71	682.67				
4							682.80	682.72				
5							682.33	682.87				
6							682.82	682.52				
7							682.27					
8							681.36	682.27				
9												
10							682.55	680.58				
11												
12							682.57	680.58				
13												
14							682.94	682.37				
15							683.18					
16							683.14	681.97				
17							683.37					
18							683.16	681.27				
19							682.90					
20							682.74	681.37				
21												
22							681.99	681.37				
23							682.14					
24						683.19	683.16	681.67				
25								682.09				
26						682.81	682.57					
27						683.18	682.73	681.83				
28												
29						684.47	683.06					
30							682.49					
31										679.69		

Revillon Coupe below confluence Riviere des Rochers -
Station 07NA004

Summary of Discharge Measurements

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 27	.51	13.15	1,620
Jul 10	.76	12.55	2,100
Jul 14	.78	12.94	2,035
Jul 16	1.11	13.14	2,860
Jul 18	1.05	13.16	2,810
Jul 20	1.21	12.74	3,030
Jul 23	.95	12.14	2,175
Jul 27	1.20	12.74	2,905
Aug 24	.81	11.67	1,710
Oct 31	.67	9.69	1,130

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 1	0.56	3.40	1,280
Jun 8	1.00		1,770
Jun 10	0.42		590
Jun 14	0.87		1,470
Jun 22	2.74	5.68	8,540 ●
Jun 24	2.22	5.80	7,090 ●
Jun 28	2.30	4.75	6,440 ●
Jun 30	0.50	4.78	1,420 ●
Jul 2	1.15	5.26	3,280 ●
Jul 5	1.56	5.70	4,750 ●
Jul 7	0.74	5.70	2,330 ●
Jul 9	0.33	5.20	990 ●
Jul 12	0.47	4.88	1,240 ●
Jul 14	1.06	5.43	3,200 ●
Jul 16	2.41	6.63	8,130 ●
Jul 21	1.46	7.21	5,130 ●
Jul 26	0.28	6.18	923
Jul 28	0.94	6.11	3,060
Jul 30	0.95	5.59	2,800
Aug 6	1.30	5.16	3,600
Aug 9	1.34	5.03	3,870
Aug 11	1.25	4.97	3,210
Aug 16	1.45	4.87	4.170
Aug 20	1.63	5.03	4,710
Aug 23	1.26	2.80	3,000
Aug 26	1.17	3.81	2,960
Sep 8	1.15	3.19	2,510
Oct 15	0.80	2.63	1,560

● Flow was southward toward Riviere des Rochers

DESCRIPTION OF HYDROMETRIC STATION

Station Name Revillon Coupe at Ranger's Cabin, station 07NA005

Latitude 58° 53' 50" N. Longitude 111° 24' 00" W. · Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

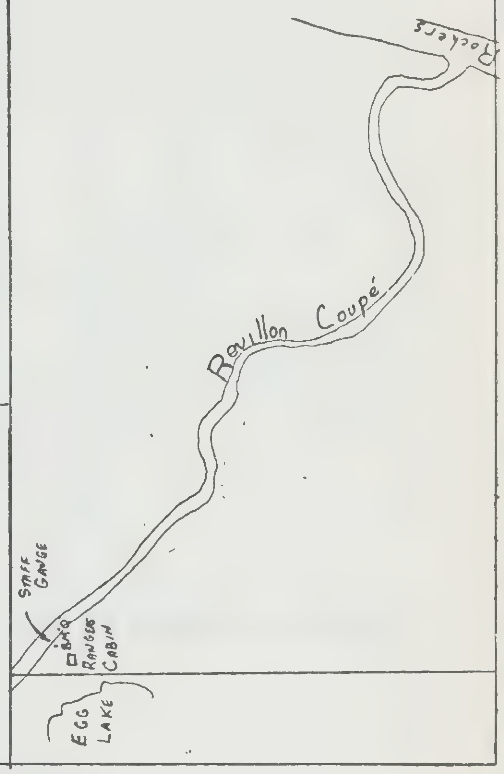
Period of Observation 1970 to present (seasonal)

Location of Station On South Bank, approximately seven miles below confluence with Riviere des Rochers

Description of Equipment Staff gauge

Remarks Stage-only type of record

LOCATION PLAN



BENCH MARKS

BM'Q' - Elevation 695.46 is brass plug (Topographic Survey of Canada) in rock outcrop on left bank.

STATION EQUIPMENT

Revillon Coupe at Ranger's Cabin - Station No. 07NA005

Daily Water Levels in Feet for Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							682.89	681.70	680.88			
2							682.52	681.79	681.76			
3							682.35	681.81	681.50			
4							682.36	681.92	680.77			
5							682.14	682.10	680.03			
6							682.29	681.99	680.03			
7							682.30	682.45				
8							682.29	682.05				
9							682.76	680.89				
10						683.32		680.30				
11						683.43	682.95	680.84				
12						683.16	682.52	681.35				
13						683.36	682.56	681.69				
14						683.28	682.62	681.54				
15						683.12	682.52	681.43				
16						682.86	682.60	681.15				
17						682.99	682.96	681.29				
18						682.62	682.60	680.71				
19						682.66	682.30	681.12				
20						682.68	682.24	680.98				
21						682.82	682.25	681.34				
22						682.88	681.85	680.99				
23						683.12	681.70	680.90				
24						682.78	682.42	680.75				
25						682.58	682.12	681.24				
26						682.58	682.00	681.39				
27						683.35	681.88	680.93				
28						683.39	681.95	680.89				
29						683.66	682.20	680.83				
30						683.11	681.75	680.47				
31							680.77	680.33				
Mean							682.29	681.26				
Max							682.96	682.45				
Min							680.77	680.30				

REVILLON COUPE AT RANGER'S CABIN - STATION NO. 07NA005

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	682.30	---	684.57	---	---	---	---	1
2	---	---	---	---	---	682.41	---	684.35	---	---	---	---	2
3	---	---	---	---	---	682.62	---	684.18	---	---	---	---	3
4	---	---	---	---	---	682.41	686.05	---	---	---	---	---	4
5	---	---	---	---	---	683.06	685.54	---	---	---	---	---	5
6	---	---	---	---	---	682.56	685.14	---	---	---	---	---	6
7	---	---	---	---	---	682.33	684.84	---	---	---	---	---	7
8	---	---	---	---	---	682.60	684.52	---	---	---	---	---	8
9	---	---	---	---	---	682.58	684.36	683.47	---	---	---	---	9
10	---	---	---	---	---	682.41	---	683.51	---	---	---	---	10
11	---	---	---	---	---	682.54	---	683.36	---	---	---	---	11
12	---	---	---	---	---	682.30	---	683.41	681.37	---	---	---	12
13	---	---	---	---	---	682.49	---	683.65	680.70	---	---	---	13
14	---	---	---	---	---	683.18	---	683.38	681.03	---	---	---	14
15	---	---	---	---	---	683.66	---	683.77	681.84	---	---	---	15
16	---	---	---	---	---	---	---	683.32	681.81	---	---	---	16
17	---	---	---	---	---	683.75	---	683.19	681.19	---	---	---	17
18	---	---	---	---	---	---	---	683.08	681.28	---	---	---	18
19	---	---	---	---	---	683.79	---	683.16	681.19	---	---	---	19
20	---	---	---	---	---	683.35	---	683.21	680.32	---	---	---	20
21	---	---	---	---	---	---	---	683.55	---	---	---	---	21
22	---	---	---	---	---	686.26	---	682.66	---	---	---	---	22
23	---	---	---	---	---	686.47	---	682.27	---	---	---	---	23
24	---	---	---	---	---	---	---	682.80	---	---	---	---	24
25	---	---	---	---	---	---	685.64	682.42	---	---	---	---	25
26	---	---	---	---	---	---	685.28	682.32	---	---	---	---	26
27	---	---	---	---	---	---	685.16	---	681.21	---	---	---	27
28	---	---	---	---	---	---	685.02	---	680.39	---	---	---	28
29	---		---	---	---	---	684.66	---	680.35	---	---	---	29
30	---		---	---	682.63	---	684.55	---	---	---	---	---	30
31	---		---		682.36		684.53	682.57		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 53 50 N
LONG 111 24 00 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Revillon Coupe above Peace confluence, station 07NA006

Latitude 58° 55' 50" N. Longitude 111° 32' 40" W. · Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

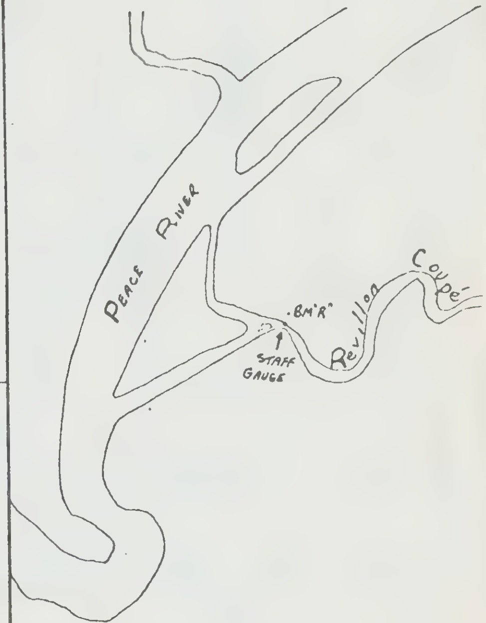
Period of Observation 1970 to present (seasonal)

Location of Station On North Bank approximately one mile above confluence with Peace River, just above island at the River Forks.

Description of Equipment Staff Gauge

Remarks

LOCATION PLAN



BENCH MARKS

BM'R' - Elevation 702.82 is twisted iron bar in concrete near yellow blazed tree about 10' from 1970 right bank

STATION EQUIPMENT

Revillon Coupe above Peace Confluence - Station No. 07NA006

Daily Water Level in Feet - for the Yr. 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								680.50				
2							682.12	680.73				
3							681.84	680.92				
4							681.80	680.92				
5							681.61	681.17				
6							681.77	681.22				
7							682.03					
8							681.75	681.37				
9												
10							682.79	679.99				
11							682.69					
12								680.37				
13												
14								680.47				
15							681.87					
16							681.98	680.27				
17							681.92					
18								679.52				
19							681.46					
20								680.17				
21												
22							680.91	679.67				
23												
24						682.53	681.16	679.67				
25												
26						682.15	680.93					
27						682.41		679.77				
28												
29						683.11	681.06					
30												
31												

REVILLON COUPE ABOVE PEACE CONFLUENCE - STATION NO. 07NA006

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	---	---	---	---	---	1
2	---	---	---	---	---	---	---	---	---	---	---	---	2
3	---	---	---	---	---	---	---	---	---	---	---	---	3
4	---	---	---	---	---	---	---	---	---	---	---	---	4
5	---	---	---	---	---	---	---	---	---	---	---	---	5
6	---	---	---	---	---	---	---	---	---	---	---	---	6
7	---	---	---	---	---	---	---	---	---	---	---	---	7
8	---	---	---	---	---	---	---	---	---	---	---	---	8
9	---	---	---	---	---	---	---	---	---	---	---	---	9
10	---	---	---	---	---	---	---	---	---	---	---	---	10
11	---	---	---	---	---	682.21	---	---	---	---	---	---	11
12	---	---	---	---	---	---	---	---	---	---	---	---	12
13	---	---	---	---	---	---	---	---	---	---	---	---	13
14	---	---	---	---	---	---	---	---	---	---	---	---	14
15	---	---	---	---	---	---	---	---	---	---	---	---	15
16	---	---	---	---	---	---	---	---	---	---	---	---	16
17	---	---	---	---	---	---	---	---	---	---	---	---	17
18	---	---	---	---	---	683.84	---	---	---	---	---	---	18
19	---	---	---	---	---	---	---	---	---	---	---	---	19
20	---	---	---	---	---	---	---	---	---	---	---	---	20
21	---	---	---	---	---	---	---	---	---	---	---	---	21
22	---	---	---	---	---	687.50	---	---	---	---	---	---	22
23	---	---	---	---	---	---	---	---	---	---	---	---	23
24	---	---	---	---	---	---	---	---	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	---	---	---	---	681.34	---	---	---	---	26
27	---	---	---	---	---	---	---	---	---	---	---	---	27
28	---	---	---	---	---	---	---	---	---	---	---	---	28
29	---		---	---	---	---	---	---	---	---	---	---	29
30	---		---	---	682.21	---	---	---	---	---	---	---	30
31	---		---		---		---	681.49		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 55 50 N
LONG 111 32 40 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Richardson Lake at the Outlet - Station No. 07DD008

Latitude 58° 23' 55"N Longitude 110° 58' 20"W . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

Period of Observation 1971 to present

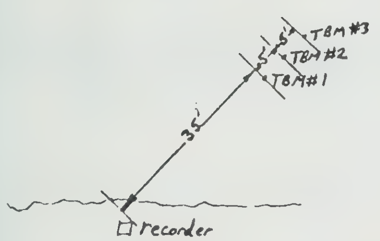
Location of Station Twenty-two and one'half miles south, 10° east of Fort Chipewyan. Two and one'half miles upstream from Jackfish Creek confluence with the Athabasca River. Located on the West side of the West channel of Jackfish Creek.

Description of Equipment

F-type recorder activated by A float.

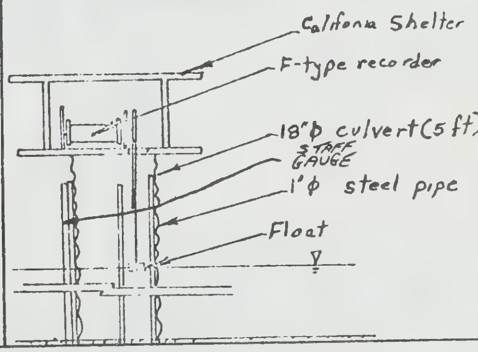
Remarks This station operated for the Peace-Athabasca Delta Study

BENCH MARKS

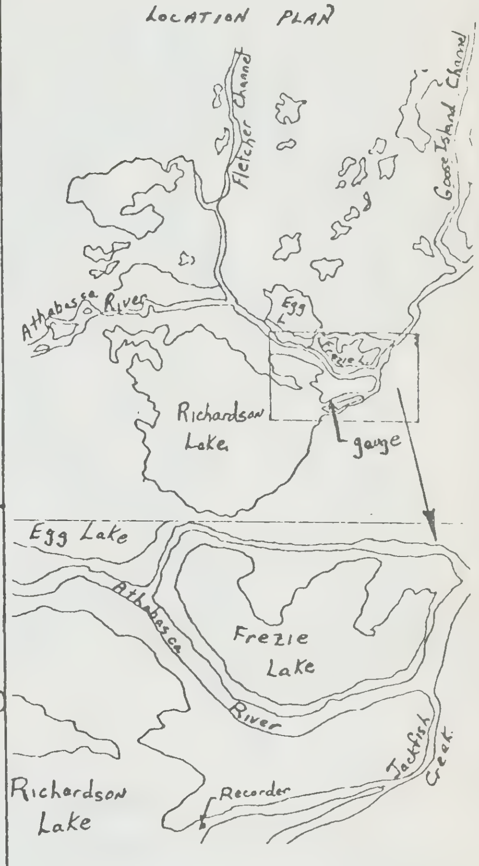


STATION EQUIPMENT

DIMENSIONED SKETCH OF ORIFICE OR INTAKES



LOCATION PLAN



RICHARDSON LAKE AT THE OUTLET - STATION NO. 07DD008

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	2.37	---	---	---	---	---	---	1
2	---	---	---	---	---	2.46	---	---	---	---	---	---	2
3	---	---	---	---	---	2.62	---	---	3.04A	---	---	---	3
4	---	---	---	---	---	2.72	---	---	3.02	---	---	---	4
5	---	---	---	---	---	2.98	---	6.02A	3.00	---	---	---	5
6	---	---	---	---	---	2.83	---	---	2.91	---	---	---	6
7	---	---	---	---	---	2.66	---	---	2.77	---	---	---	7
8	---	---	---	---	---	2.81	6.70A	---	2.75	---	---	---	8
9	---	---	---	---	---	2.82	---	---	2.71	---	---	---	9
10	---	---	---	---	---	2.86	---	---	2.67	---	---	---	10
11	---	---	---	---	---	2.96	---	---	2.55	---	---	---	11
12	---	---	---	---	---	3.33	---	---	2.38	---	---	---	12
13	---	---	---	---	---	3.61	---	---	2.70	---	---	---	13
14	---	---	---	---	---	3.84	---	---	2.40	---	---	---	14
15	---	---	---	---	---	4.42	---	---	2.42	---	---	---	15
16	---	---	---	---	---	5.02	---	---	2.26	---	---	---	16
17	---	---	---	---	---	5.50	---	---	2.07	---	---	---	17
18	---	---	---	---	---	5.72	---	---	2.23	---	---	---	18
19	---	---	---	---	---	5.85	---	4.51A	2.43	---	---	---	19
20	---	---	---	---	---	5.93A	---	---	2.30	---	---	---	20
21	---	---	---	---	---	---	---	---	2.31	1.44A	---	---	21
22	---	---	---	---	---	6.27A	---	---	2.29	---	---	---	22
23	---	---	---	---	3.07A	---	---	---	2.22	---	---	---	23
24	---	---	---	---	2.99	---	---	---	2.26	---	---	---	24
25	---	---	---	---	2.80	---	---	---	2.31	---	---	---	25
26	---	---	---	---	2.64	---	---	---	2.05	---	---	---	26
27	---	---	---	---	2.53	---	---	---	1.90	---	---	---	27
28	---	---	---	---	2.39	---	---	---	1.80	---	---	---	28
29	---		---	---	2.38	---	---	---	1.76A	---	---	---	29
30	---		---	---	2.36	---	---	---	---	---	---	---	30
31	---		---		2.29		---	---		---		---	31

A-MANUAL GAUGE

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 23 55 N
LONG 110 58 20 W

WATER LEVELS ARE REFERRED TO ASSUMED DATUM.

Richardson Lake at the Outlet - Station No. 07DD008

Daily Elevations in Feet for the Year 1972

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							692.78	690.32	688.49			
2							693.33	690.38	688.46			
3							693.74	690.52	688.76			
4							693.90	690.46	688.37			
5							693.95	690.46	688.31			
6							693.92	690.45	688.25			
7							693.73	690.38	688.20			
8							693.48	690.30	688.14			
9						690.81	693.18		688.09			
10						690.78	693.17		688.01			
11						690.65	692.98		687.92			
12						690.53	692.60		687.98			
13						690.40	692.35		688.21			
14						690.40	692.13	689.86	687.95			
15						690.39	692.01	689.76	687.70			
16						690.48	692.00	689.73	687.78			
17						690.65	691.99	689.72	687.99			
18						691.30	691.93	689.84	688.06			
19						691.81	691.78	689.87	687.83			
20						692.19	691.59	689.82	687.61			
21						692.40	691.41	689.70	688.11			
22						692.51	691.31	689.58	687.93			
23						692.59	691.19	689.47	688.30			
24						692.62	691.06	689.37	688.52			
25						692.58	690.98	689.21	688.56			
26						692.51	690.85	689.13	688.48			
27						692.38	690.74	689.02	688.63			
28						692.29	690.62	688.81				
29						692.29	690.51	688.80				
30						692.33	690.42	688.63				
31							690.31	688.61				
Mean												
Max												
Min												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Riviere des Rochers above Peace-Slave confluence - Station 07NA001

Latitude 58° 59' 40" N. Longitude 111° 24' 10"W. . Sec Twp Rge

Established 1960
Re-established 1970
Re-established 1971

Observer

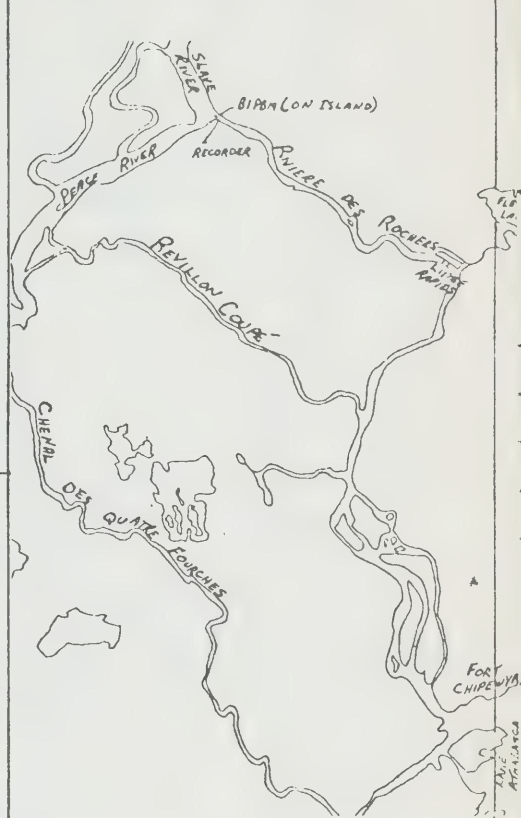
Period of Observation 1970 to present (seasonal)

Location of Station On the southwest bank of the Riviere des Rochers approximately 1,000 ft. above its confluence with the Peace River.

Description of Equipment A-35 Recorder activated by a float; 8 ft. staff gauge.

Remarks This station is operated for the Peace-Athabasca Delta Study.

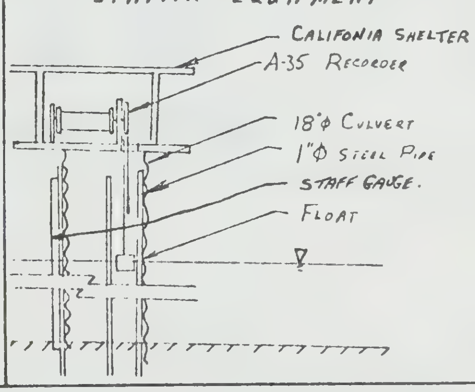
LOCATION PLAN



BENCH MARKS

BIPM - Elevation 688.15 is a yellow X painted on rock at the base of a bent 1" diameter iron bar in outcrop in Riviere des Rochers just above Peace-Slave confluence.

STATION EQUIPMENT



Riviere des Rochers above Peace-Slave confluence - Station 07NA001

Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								678.97				
2							681.04	679.27				
3							680.77	679.49				
4							680.72	679.55				
5							680.49	679.81				
6							680.59	679.96				
7							680.87					
8							680.70	680.06				
9												
10								678.56				
11						682.78	681.55					
12						682.45		678.81				
13						682.64						
14						682.48	680.99	678.96				
15						682.30	680.80					
16						681.88	681.15	678.56				
17						682.08						
18						681.80		678.06				
19						681.39	680.27					
20						681.30		678.41				
21						681.26	679.47					
22						681.44		678.21				
23						681.50						
24						681.37	679.47	678.26				
25												
26						681.02	679.61					
27						681.36		678.34				
28						682.14						
29							679.61					
30							679.45					
31												

RIVIERE DES ROCHERS ABOVE PEACE-SLAVE CONFLUENCE - STATION NO. 07NA001

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	682.72	680.04	678.66	---	---	1
2	---	---	---	---	---	---	---	682.50	680.52	678.68	---	---	2
3	---	---	---	---	---	---	---	682.24	680.25	678.78	---	---	3
4	---	---	---	---	---	---	---	682.06	679.63	678.96	---	---	4
5	---	---	---	---	---	---	---	682.04	679.49	679.02	---	---	5
6	---	---	---	---	682.28A	---	---	681.83	679.21	679.18	---	---	6
7	---	---	---	---	---	---	---	681.72	678.99	678.67	---	---	7
8	---	---	---	---	---	---	---	681.46	678.87	678.89	---	---	8
9	---	---	---	---	---	---	---	681.15	678.91	678.68	---	---	9
10	---	---	---	---	---	---	---	681.07	679.00	678.60	---	---	10
11	---	---	---	---	---	677.56A	---	681.00	679.18	678.98	---	---	11
12	---	---	---	---	---	---	---	680.93	678.81	678.95	---	---	12
13	---	---	---	---	---	---	683.88A	680.55	678.48	679.71	---	---	13
14	---	---	---	---	---	---	---	680.64	678.38	679.87	---	---	14
15	---	---	---	---	---	---	---	681.08	679.03	679.81	---	---	15
16	---	---	---	---	---	---	---	680.80	679.14	679.48	---	---	16
17	---	---	---	---	---	679.48A	686.14A	680.61	678.80	679.23	---	---	17
18	---	---	---	---	---	---	686.31	680.51	678.92	679.02	---	---	18
19	---	---	---	---	---	---	686.20	680.46	679.01	678.82	---	---	19
20	---	---	---	---	---	---	686.09	680.54	679.19	678.76	---	---	20
21	---	---	---	---	---	---	685.80	680.57	679.11	678.50	---	---	21
22	---	---	---	---	---	---	685.47	680.31	679.26	678.51	---	---	22
23	---	---	---	---	---	---	685.48	679.91	679.43	678.38	---	---	23
24	---	---	---	---	---	---	684.74	679.84	679.83	678.39	---	---	24
25	---	---	---	---	---	---	684.24	679.87	680.13	677.89	---	---	25
26	---	---	---	---	---	---	684.04	679.78	679.78	677.87	---	---	26
27	---	---	---	---	---	---	683.89	679.91	679.10	678.46A	---	---	27
28	---	---	---	---	---	---	683.51	680.03	678.55	---	---	---	28
29	---		---	---	680.81A	---	683.19	679.92	678.46	---	---	---	29
30	---		---	---	---	---	682.95	679.87	678.59	---	---	---	30
31	---		---		---		682.78	679.92		---		---	31

A-MANUAL GAUGE

TYPE OF GAUGE - RECORDING
LOCATION - LAT 58 59 40 N
LONG 111 24 10 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

Riviere des Rochers above Peace-Slave confluence - Station 07NA001

Daily Elevations in Feet for the Year 1972

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							687.70					
2							687.70					
3							687.54					
4							687.32					
5							687.14					
6							686.93					
7							686.73					
8							686.48					
9							686.50					
10							686.84					
11							686.17					
12												
13												
14						684.58						
15						684.43						
16						686.32						
17						688.35						
18						688.74						
19						687.99						
20						687.56						
21						687.64						
22						687.86						
23						687.97						
24						687.77						
25						687.57						
26						687.55						
27						687.55						
28						687.55						
29						687.48						
30						687.35						
31												

DESCRIPTION OF HYDROMETRIC STATION

Station Name Riviere des Rochers at Ben Houle's Cabin, station 07NA002

Latitude 58° 49' 10" N. Longitude 111° 16' 30" W. • Sec Twp Rge

Established 1960
Re-established
Re-established

Observer

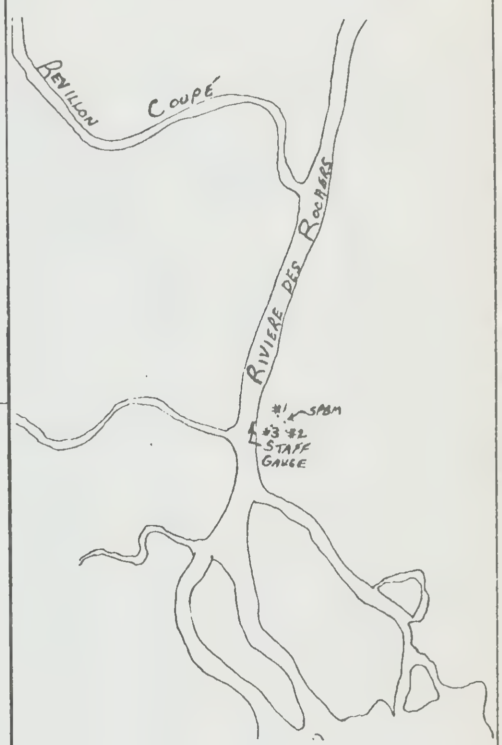
Period of Observation 1960, 1970 to present

Location of Station On right bank, approximately twelve miles by boat from Fort Chipewyan, up the Riviere des Rochers.

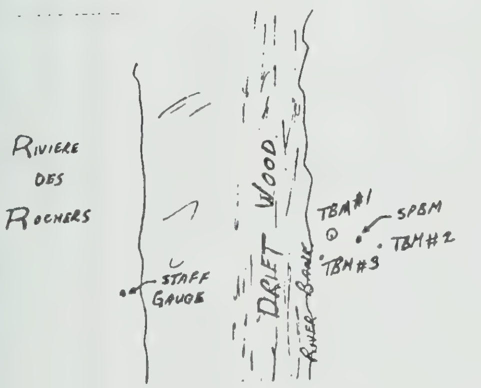
Description of Equipment Staff gauge

Remarks Discharge measurement site. Most 1970 measurements were taken near the confluence of Revillon Coupe. Sediment data collected in 1971.

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

Riviere des Rochers at Ben Houle's Cabin - Station 07NA002

Daily Elevations in Feet for the Year 1971

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						683.12						
2						683.27	685.05					
3						683.36		685.24				
4						683.15						
5						684.00	685.37	685.38				
6								684.89				
7							685.33	684.98				
8						683.45			682.66	681.99		
9						683.49	684.94	684.76	682.53			
10						683.07						
11						683.05		684.77				
12							684.52	684.67				
13								684.03				
14						683.98	685.20					
15						684.27	685.84			682.15		
16						684.40	686.22	684.84				
17						683.83		684.43	681.93			
18						684.05		684.44				
19						683.93	686.70					
20								684.60				
21						684.31	686.61		682.61			
22						685.27	686.36					
23						685.42		683.78				
24						685.68		683.65				
25						685.22		683.84				
26								683.51				
27					683.36			683.83	682.20			
28						684.18	685.82		681.49			
29					683.57							
30						684.42	685.40		681.91			
31								683.96				

Riviere des Rochers at Ben Houle's Cabin - Station 07NA002

Summary of Discharge Measurements

1971

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jan 5	0.88		21,700
Feb 17	0.43		9,010
Mar 16	0.40		8,700
May 27	2.29	3.00	67,900
Jun 1	2.17	2.85	62,600
Jun 3	2.33	4.61	68,200
Jun 5	2.55	5.25	76,900
Jun 8	2.45	4.70	73,000
Jun 9	2.49	4.74	73,600
Jun 10	2.28	4.32	66,700
Jun 14	2.42	5.23	73,400
Jun 16	1.92	5.65	58,000
Jun 19	1.89	5.18	57,500
Jun 21	1.22	5.56	37,000
Jun 23	0.61	6.67	19,300 ●
Jun 25	0.81	5.43	25,400
Jun 28	1.34	5.43	40,000
Jun 30	1.91	5.67	58,300
Jul 2	1.56	6.30	48,900
Jul 5	1.13	6.48	35,400
Jul 7	1.58	6.44	49,500
Jul 9	2.03	6.05	63,000
Jul 12	1.98	5.63	59,300
Jul 14	1.72	6.19	54,100
Jul 16	0.91	7.33	29,500
Jul 19		7.52 max 6.70 min	
Jul 21	1.36	4.45	44,200
Jul 28	2.59	3.63	82,900
Jul 30	2.48	3.25	77,400

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Aug 3	2/85	3.09	90,300
Aug 6	2.71	2.77	85,500
Aug 9	2.90	3.56	91,500
Aug 12	2.74	3.46	84,900
Aug 13	2.77	2.82	85,300
Aug 17	2.85	3.21	88,800
Aug 20	2.92	3.38	90,500
Aug 23	2.77	2.55	83,700
Aug 26	2.69	2.38	74,500
Sep 8	2.22	1.47	76,500
Sep 17	2.27	0.78	65,600
Sep 28	2.11	0.38	59,200
Oct 15	2.04	1.07	58,800

● Flow was southward toward Lake Athabasca

Riviere des Rochers at Ben Houle's Cabin - Station 07NA002

Summary of Discharge Measurements

1970

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jun 12	1.22		37,540
Jun 14	1.65		52,670
Jun 22	2.17		68,780
Jul 9	2.23		58,860
Jul 14	2.31	12.94	62,910
Jul 16	2.43	13.14	68,000
Jul 18	2.44	13.16	69,530
Jul 20	2.50	12.74	71,330
Jul 23	2.48	12.14	69,490
Jul 27	2.55	12.73	73,220
Aug 24	2.44	11.67	65,810
Nov 1	2.20	9.68	56,380

1972

Date	Mean Velocity fps	Mean Gauge Height ft	Discharge cfs
Jan 29	1.10		19,400
Jan 31	.91		16,000
Mar 13	.72		10,100
Mar 20	.88		12,300
Mar 24	.82		11,200
Apr 7	.79		11,600
Apr 12	.85		11,900
Apr 21	.98		14,600

DESCRIPTION OF HYDROMETRIC STATION

Station Name Riviere des Rochers above confluence Revillon Coupe, station 07NA003

Latitude 58° 50' 30" N. Longitude 111° 16' 00" W. . Sec Twp Rge

Established 1971
Re-established
Re-established

Observer

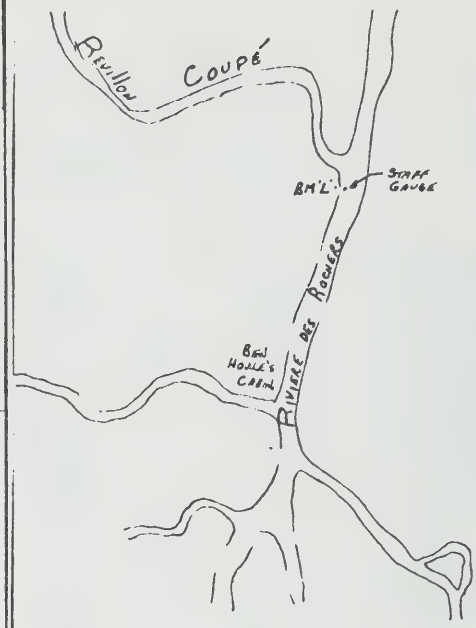
Period of Observation 1971 to present (seasonal operation)

Location of Station On left bank, approximately five hundred feet above the confluence with Revillon Coupe.

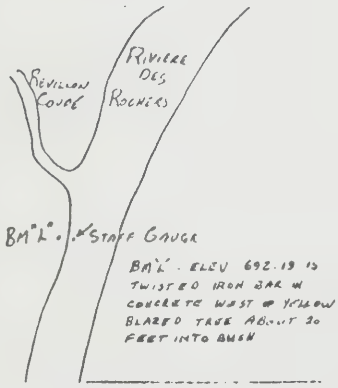
Description of Equipment Staff Gauge

Remarks Stage-only type of record.

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

RIVIERE DES ROCHERS ABOVE CONFLUENCE REVILLON COUPE - STATION NO. 07NA003

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	682.70	---	---	---	---	---	---	1
2	---	---	---	---	---	682.82	684.58	---	---	---	---	---	2
3	---	---	---	---	---	682.97	---	---	---	---	---	---	3
4	---	---	---	---	---	---	---	---	---	---	---	---	4
5	---	---	---	---	---	---	685.02	---	---	---	---	---	5
6	---	---	---	---	---	---	---	684.50	---	---	---	---	6
7	---	---	---	---	---	---	685.02	684.56	---	---	---	---	7
8	---	---	---	---	---	---	---	---	682.52	681.66	---	---	8
9	---	---	---	---	---	---	684.52	684.38	682.17	---	---	---	9
10	---	---	---	---	---	---	---	---	---	---	---	---	10
11	---	---	---	---	---	---	---	684.32	---	---	---	---	11
12	---	---	---	---	---	---	684.21	---	---	---	---	---	12
13	---	---	---	---	---	684.33	684.35	---	---	---	---	---	13
14	---	---	---	---	---	---	684.76	---	---	---	---	---	14
15	---	---	---	---	---	---	---	---	---	681.94	---	---	15
16	---	---	---	---	---	684.09	685.96	684.22	---	---	---	---	16
17	---	---	---	---	---	683.52	---	---	---	---	---	---	17
18	---	---	---	---	---	---	---	---	---	---	---	---	18
19	---	---	---	---	---	---	685.98	---	---	---	---	---	19
20	---	---	---	---	---	---	---	684.38	---	---	---	---	20
21	---	---	---	---	---	684.29	686.54	---	682.26	---	---	---	21
22	---	---	---	---	---	684.99	685.51	---	---	---	---	---	22
23	---	---	---	---	---	---	---	682.15	---	---	---	---	23
24	---	---	---	---	---	685.12	---	683.37	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	---	---	---	685.51	683.12	---	---	---	---	26
27	---	---	---	---	682.92	---	---	684.36	---	---	---	---	27
28	---	---	---	---	---	684.07	685.44	---	---	---	---	---	28
29	---		---	---	683.15	---	---	---	---	---	---	---	29
30	---		---	---	683.04	684.10	684.93	---	681.43	---	---	---	30
31	---		---		---		685.05	683.56		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 50 30 N
LONG 111 16 00 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Riviere des Rochers east of Little Rapids station 07NA007

Latitude 58° 54' 55" N. Longitude 111° 10' 30" W. . Sec Twp Rge

Established 1960
Re-established 1970
Re-established

Observer

Period of Observation 1960, 1970 to present (seasonal operations)

Location of Station On right bank, approximately nineteen miles by boat from Fort Chipewyan up the Riviere des Rochers. Located 400 feet up small channel.

Description of Equipment Staff gauge

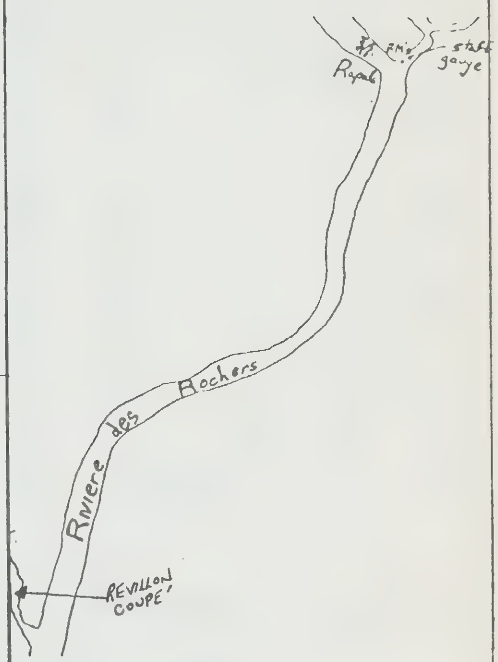
Remarks Stage-only type of record.

BENCH MARKS

BM's located just above Rochers Rapids at tip of Island.
SIBM 1 Elevation 693.40' is standard iron bench mark.
SIBM 2 Elevation 692.60' is standard iron bench mark.
SIBM 3 Elevation 692.27' (Revised 1970) is standard iron bench mark.

STATION EQUIPMENT

LOCATION PLAN



Riviere des Rochers east of Little Rapids - Station 07NA007

Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								681.99				
2							682.95	682.11				
3							682.58	682.31				
4							682.66	682.36				
5							682.31	682.46				
6							682.69	682.21				
7							682.19					
8							681.19	682.06				
9												
10								680.86				
11						683.53						
12						682.98	682.41	681.71				
13						683.55						
14					682.27	683.46	682.81	682.06				
15						683.39	682.84					
16						682.85	682.90	681.56				
17						683.28	683.01		680.24			
18						682.94	682.83	681.11				
19						682.82	682.66		679.92			
20						682.75		681.11	679.84			
21						683.08						
22						683.32	681.80	681.11				
23						683.37						
24						682.77	682.69	681.26				
25								681.59				
26						682.72	682.26					
27						683.14		681.48				
28												
29						684.31	682.63					
30							682.12					
31												

RIVIERE DES ROCHERS EAST OF LITTLE RAPIDS - STATION NO. 07NA007

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	---	---	---	---	---	1
2	---	---	---	---	---	---	---	---	---	681.32	---	---	2
3	---	---	---	---	---	682.80	---	---	---	---	---	---	3
4	---	---	---	---	---	---	---	---	---	681.31	---	---	4
5	---	---	---	---	---	---	---	---	---	---	---	---	5
6	---	---	---	---	---	---	---	684.11	---	681.60	---	---	6
7	---	---	---	---	---	---	---	684.13	---	---	---	---	7
8	---	---	---	---	---	---	---	---	681.81	681.45	---	---	8
9	---	---	---	---	---	---	---	684.09	681.73	---	---	---	9
10	---	---	---	---	---	---	---	683.87	---	---	---	---	10
11	---	---	---	---	---	682.58	---	---	---	681.59	---	---	11
12	---	---	---	---	---	---	684.07	683.69	---	---	---	---	12
13	---	---	---	---	---	---	684.59	---	---	681.98	---	---	13
14	---	---	---	---	---	---	684.79	---	---	---	---	---	14
15	---	---	---	---	---	---	---	---	---	681.62	---	---	15
16	---	---	---	---	---	---	685.85	683.67	---	---	---	---	16
17	---	---	---	---	---	683.49	---	683.60	---	---	---	---	17
18	---	---	---	---	---	---	---	---	---	681.06	---	---	18
19	---	---	---	---	---	---	686.03	---	---	---	---	---	19
20	---	---	---	---	---	---	---	683.88	---	---	---	---	20
21	---	---	---	---	---	---	---	---	681.90	---	---	---	21
22	---	---	---	---	---	---	---	---	---	---	---	---	22
23	---	---	---	---	---	---	---	682.69	---	---	---	---	23
24	---	---	---	---	---	---	---	682.85	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	---	---	---	---	---	---	---	---	---	26
27	---	---	---	---	---	---	---	---	680.58	---	---	---	27
28	---	---	---	---	---	---	---	---	---	---	---	---	28
29	---		---	---	682.89	---	---	---	---	---	---	---	29
30	---		---	---	---	---	---	---	681.13	---	---	---	30
31	---		---		---		684.72	---		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 54 55 N
LONG 111 10 30 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

DESCRIPTION OF HYDROMETRIC STATION

Station Name Riviere des Rochers West of Little Rapids, station 07NA008

Latitude 58° 55' 35" N. Longitude 111° 12' 15" W. Sec Twp Rge

Established 1960
Re-established 1970
Re-established

Observer

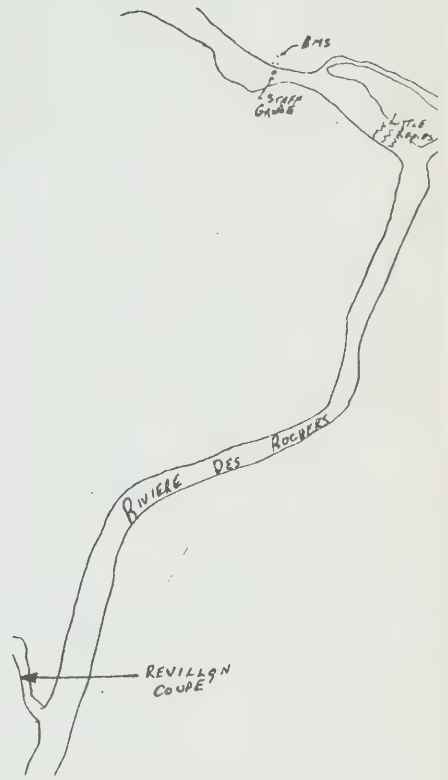
Period of Observation 1960, 1970 to present (seasonal operations)

Location of Station On right bank, approximately twenty miles from Fort Chipewyan up the Riviere des Rochers.

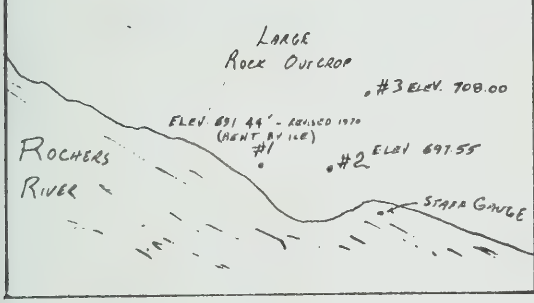
Description of Equipment Staff gauge

Remarks Stage-only type of record

LOCATION PLAN



BENCH MARKS



STATION EQUIPMENT

Riviere des Rochers West of Little Rapids, Station 07NA008
Daily Elevations in Feet for the Year 1970

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								679.73				
2							681.65	679.98				
3							681.33	680.18				
4							681.27	680.25				
5							681.01	680.48				
6							681.25	680.51				
7							681.18					
8							680.67	680.58				
9												
10								679.20				
11						683.07						
12						682.66		679.48				
13						682.98						
14						682.90		679.73				
15						682.71						
16						682.30		679.28				
17						682.51			678.19			
18						682.21		678.68				
19						681.87			677.98			
20						681.79		678.88	677.96			
21						681.87						
22						682.08		678.93				
23						682.14						
24						681.79	678.93					
25							679.10					
26						681.54						
27						681.93		678.97				
28												
29						682.92	680.38					
30							680.08					
31												

RIVIERE DES ROCHERS WEST OF LITTLE RAPIDS - STATION NO. 07NA008

DAILY WATER LEVEL IN FEET FOR 1971

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	---	---	---	---	---	---	---	---	---	---	1
2	---	---	---	---	---	---	---	---	---	679.40	---	---	2
3	---	---	---	---	---	681.56	---	---	---	---	---	---	3
4	---	---	---	---	---	---	---	---	---	679.61	---	---	4
5	---	---	---	---	---	---	---	---	---	---	---	---	5
6	---	---	---	---	---	---	---	682.69	---	679.94	---	---	6
7	---	---	---	---	---	---	---	682.63	---	---	---	---	7
8	---	---	---	---	---	---	---	---	679.95	---	---	---	8
9	---	---	---	---	---	---	---	682.02	679.79	---	---	---	9
10	---	---	---	---	---	---	---	---	---	---	---	---	10
11	---	---	---	---	---	681.35	---	---	---	679.85	---	---	11
12	---	---	---	---	---	---	683.27	682.02	---	---	---	---	12
13	---	---	---	---	---	---	683.96	---	---	680.65	---	---	13
14	---	---	---	---	---	---	684.28	---	---	---	---	---	14
15	---	---	---	---	---	---	---	---	---	680.34	---	---	15
16	---	---	---	---	---	---	---	681.95	---	---	---	---	16
17	---	---	---	---	---	682.90	---	---	---	---	---	---	17
18	---	---	---	---	---	---	---	681.69	---	679.50	---	---	18
19	---	---	---	---	---	---	685.93	---	---	---	---	---	19
20	---	---	---	---	---	---	---	681.94	---	---	---	---	20
21	---	---	---	---	---	---	---	---	679.97	---	---	---	21
22	---	---	---	---	---	---	---	---	---	---	---	---	22
23	---	---	---	---	---	---	---	680.99	---	---	---	---	23
24	---	---	---	---	---	---	---	680.92	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	---	---	---	---	---	---	---	---	---	26
27	---	---	---	---	---	---	---	681.00	679.74	---	---	---	27
28	---	---	---	---	---	---	---	---	---	---	---	---	28
29	---		---	---	681.47	---	---	---	---	---	---	---	29
30	---		---	---	---	---	---	---	679.19	---	---	---	30
31	---		---		---		683.57	---		---		---	31

TYPE OF GAUGE - MANUAL
LOCATION - LAT 58 55 35 N
LONG 111 12 15 W

REGULATED SINCE 1967

WATER LEVELS ARE REFERRED TO GEODETIC SURVEY OF CANADA DATUM.

SECTION L

SECTION L

THE QUATRE FOURCHES IMPOUNDMENT

J. R.CARD
HYDROLOGY BRANCH
ALBERTA ENVIRONMENT
EDMONTON

D. W. STREET
NATIONAL AND HISTORIC PARKS
DEPT. INDIAN AFFAIRS AND
NORTHERN DEVELOPMENT
CALGARY

1972

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THE QUATRE FOURCHES IMPOUNDMENT

INTRODUCTION

By the fall of 1971, an initial assessment of the changing conditions in the Delta had made it clear that immediate action was necessary to halt the progress of ecological succession that had commenced during the previous four summers of low water. The Quatre Fourches Dam was adopted as a temporary measure until a more permanent solution could be determined. The dam, consisting of a rockhill plug, was constructed at the outlet of Mamawi Lake (Figure 1), at a cost of $200,000. The purpose of this dam was to impound water from the Birch River basin to raise the water levels of Lakes Claire and Mamawi and of adjacent ponds and perched basins. The Peace River can overtop its banks and also flood the northern part of the Delta during high flood flows and ice jams in the spring. This, too, can help to improve the water levels of Lakes Claire and Mamawi and of the perched basins along the Peace. The success of the temporary dam, therefore depended on the amount of runoff from the Birch River and the frequency with which the combination of high floods and ice jams might occur on the Peace River.

Recognizing these considerations, a flexible approach was adopted in the design and construction of the Quatre Fourches Dam. In the fall of 1971 the dam was completed to an elevation of 684 feet. At this height water could still flow in from Lake Athabasca, should high Lake levels occur. In the spring, the dam was completed to elevation of 688.5 and temporary arrangements were made for the passage of goldeye and other fish.

EFFECTS OF THE 1972 SPRING FLOOD ON THE DELTA

The spring of 1972 brought a substantial runoff in the Birch River which helped fill Lakes Claire and Mamawi to very acceptable levels of 688.5 feet. Also, fortuitous ice jams on the Peace River created high river levels that

caused a significant volume of water to overflow its banks into the Delta, filling all the perched basins north of Lake Claire and also raising the level of Baril Lake to 689 feet. The impoundment structure at Quatre Fourches held the inflowing water at the desired level and prevented the rapid recession of the lakes which otherwise would have occurred.

Later, heavy early summer rainstorms in the Smoky River basin and in the headwaters of the Peace produced a flow that caused the Peace River to rise to approximately 689 feet at its confluence with the Riviere des Rochers. This moderately high river level, combined with a substantial inflow to Lake Athabasca from the Athabasca River, caused the Lake level to rise to elevation 688.5 feet in July.

Through this combination of fortunate occurrences, water levels in Lake Athabasca and the Delta in 1972 approached the normal summer levels. These occurrences were rare events, however, and cannot be considered as typical conditions. The flood on the Smoky River, for instance, is estimated to happen an average of once in 500 years. Similarly, the appearance to two large ice jams on the Peace River is possibly a once-in-10-year event. A large ice jam at the right point, lasting for several days, can trigger a reverse flow on the Quatre Fourches and Riviere des Rochers, resulting in a considerable diversion of water into Lake Athabasca and the Delta. While such unpredictable events cannot be relied upon in resolving low-water problems, their possibility must be considered in any proposals for remedial works.

These unusual floods and ice jams have provided a short but important breathing period in which to consider action and construct works to restore the water levels of Lake Athabasca. Although the urgency has been reduced to some degree, the necessity for remedial action is still the paramount consideration.

SUITABILITY AS A PERMANENT STRUCTURE

The Quatre Fourches structure has provided an ideal interim approach to flooding much of the Delta. But, because it controls water within the National Park, its suitability as a long-term solution should be assessed in terms of how close it comes to re-createing natural conditions. From this standpoint, it has several disadvantages. It is a barrier to fish migration between wintering sites and major spawning lakes. Even with the installation of adequate fishways, changes in the natural flow patterns may affect fish movement. If possible, barriers across major fish migration routes should be avoided.

Furthermore, it would be extremely difficult to duplicate the timing and amplitude of the natural Delta water regime because only during infrequent periods would westward flow of water from Lake Athabasca occur. Claire and Mamawi Lakes would then have to rely almost entirely on the limited water supply from the Birch River, McIvor River, and other minor tributaries.

With this pattern of water flow, the chemical quality of the Delta waters would likely deteriorate because of the lack of flushing action that was provided under natural conditions from Lake Athabasca and the Peace River. Similarly, the inflow of detritus from the Peace River, Athabasca River and Lake Athabasca, plus their silt loads deposited in the Delta, would be greatly reduced. Over a long period of time, these would significantly change the composition of the microscopic flora and fauna of the major Delta lakes, and might affect the food chain of many vertebrates.

In addition, the Quatre Fourches structure affects only 60% of the Delta. It would not alleviate low levels within the Chipewyan Indian Reserve or in remaining marshes outside the Park.

Thus, the levels of Lake Athabasca are the key to the Delta water levels and their effect on ecology within the Delta. Only by controlling the levels

of Lake Athabasca is it possible to re-create natural flow patterns within the Delta.

SUMMARY OF CONSTRUCTION

This project of an end dumped rockfill dam was initiated on September 29, 1971, with the instruction that National and Historic Parks Branch through the Western Regional Office and the assigned Area Engineer supervise the installation of the impoundment to ensure that there would be a minimum of environmental impairment to the park. The project was funded by the Department of the Environment with funds transferred to I.A.N.D.

Visits were made to the site in company with the contractor; D. M. Hornby, P.A.D.P. Director and National Parks Personnel to determine the best locations for the work camp, contractor's facilities, location of rock excavation work and extent, environmental protection, contractor site limitations, access haul road location and related work.

Barges having on board most of the material required for construction arrived on the site October 10, 1971, along with the contractor, Leckner Contracting Ltd., who proceeded to unload the camp, fuel, equipment and explosives. The contractor's forces were oriented in the intervening week and work started with drilling operations in the quarry area on October 15, 1971.

Drilling, shattering and placement of rock proceeded quickly and efficiently on the access haul road from the quarry to the north channel bank and thereafter to the rock island. The first portion of the impoundment from north bank to the rock island, approximately one-third of the weir

structure was completed by October 29, 1971.

Work advanced rapidly forming the south arm of the dam across the channel from Rock Island to the south bank. Substantial completion of the whole operation was achieved on November 29, 1971. Culverts with flap gates were installed December 5 and December 6, and fish flume work was completed December 7. Stockpiling of rock for Stage II work was completed December 9, 1971.

CONSTRUCTION CHRONOLOGY

Quarry

- drilling procedure began on Friday, October 15, 1971.
- site is procambrian rock outcropping and is control surveyed both ground and aerial.
- the quarry was benched at the access haul road elevation approximately 4-0' above average ground terrain.

This was done to:

(a) to provide a solid foundation for future shattered rock excavation storage. (estimated at 12,968 cyds.)

(b) to provide an access haul road without grades to dam-site area for haul purposes.

(c) provide an area for environmental control for replacement of topsoil for re-growth of grass and willows, where the rock has been removed.

- all shattering was well controlled, very minor overbreak, and minor rock spray conditions were evident.

Access Haul Road

From the Quarry site to north bank of the river channel;

- started 3:00 P.M., October 20, 1971.
- reached the north bank at 5:00 P.M., October 22, 1971
- length of road to north bank 800 feet.

Dam Connection at North Abutment

- started 7:30 a.m., October 23, 1971
- completed 5:00 p.m., October 23, 1971

North Arm of the Dam

- started 5:00 p.m., October 23, 1971
- completed to elevation 690 - 12 noon, October 29, 1971
- removed to elevation 664 - December 7, 1971

South Arm of the Dam

- started 8:00 a.m., November 1, 1971
- completed 5:00 p.m., November 12, 1971

Dam Connection South Abutment

- revised details received from design consultant, November 15, 1971
- rock placement completed November 17, 1971

ENVIRONMENTAL CONTROL

- access roads to unload equipment, supplies and camp accommodation and access to explosive shed were cleaned up on an 'on-going' basis during construction of the dam. Swamp willows are buried and topsoil was replaced where required for re-growth. Conditions well under control.
- quarry site was chosen, and quarry face selected in such a manner as to be completely hidden by existing growth of grass and swamp willows in the area.
- when project is completed, quarry face and access road to dam-site will by 98% obscured by old growth and areas are being propared now for re-growth.

FISH FLUME

- open flume to be constructed on immediate south side of Rock Island in conjunction with a 30" and 18" culverts with flap gates on Lake Mamawi side.

  The culverts are intended to provide attraction water flow for the fish flume arrangement.
- all the fish flume and culvert work was installed on the rock shelf of Rock Island to provide as much protection as possible for the dam structure proper. All work was as per instructions in J. M. Millen's letter of October 15, 1971.
- these items have all been discussed with Messrs. Card, Townsend, Kooyman and Millen, who all have a direct interest in the eventual outcome and success of the fish control arrangements.

SUMMARY OF FINAL QUANTITIES

A) Total calculated quanties of

Rock excavation: Stage I			27,849 cyds. total
Rock Stockpile: Stage II	a)	core materials	5,099 cyds.
	b)	shell materials	7,871 cyds.

B) Rock excavation installed

1) Impoundment weir up to elevation 684'0" — 14,817 cyds.

2) Access haul road — 2,721 syds.

C) Culverts installed

one -- 18" diameter x 74'0" long with flap gate

one -- 30" diameter x 74'0" long with flap gate

SUMMARY OF MILESTONE DATES

a) Camp setup -- October 10, 1971

b) Construction work started -- October 15, 1971

c) Contract Required completion date -- December 11, 1971

d) Contract and force account completion date -- December 9, 1971

e) Certificate of completion date (Rock Stage I) -- December 9, 1971

f) Final day on site -- December 10, 1971.

FINANCIAL

All Funding under Financial Code 4-17-000-0000-000-00-1800

Maximum Expendiutre - $200,000.00

1. Main Contract for rock excavation and placing rock on the impoundment of the Chenal des Quatre Fourche River is for $96,000.00.

   Maximum rock excavation quantities permitted under this contract are 30,000 cu. yrds. at $3.15 per cubic yard.

   In addition, this contract provides for the placing and distributing of top soil over disturbed areas in the amount of 1,000 cu. yd. at $1.50 per cubic yard.

   Final rock excavation quantities certified to this contract are 27,849 cu. yds.

Final rock expenditure is 27,849 x $3.15 per cu. yd.	$87,724.35
Top soiling, if required, in spring of 1972	1,500.00
Total expenditure under this contract	$89,224.35
Original Contract Amount	96,000.00
Surplus available from funding	6,775.65
If topsoiling is deleted from the contract then additional surplus of will be available	1,500.00
Net surplus based on above description	$ 8,275.65
Expenditures to January 31, 1972 on this contract	$87,724.35

2. The use of Department of Public Works Services to supplement inspection and control of the contractor was undertaken with a

certification of funds in the amount of	$8,000.00
Total expenditures on this commitment are not expected to exceed $7,000	7,000.00
No billings have been received to January 31, 1972	
Expected surplus from this account	$1,000.00

3. A contract for survey and staking to indicate a ground elevation of 688'0" for water supply level studies on Lakes Mamawi, Claire and Baril was awarded in the amount of $20,000.00.

   This contract is being field administered by Peace-Athabasca Delta Project personnel and invoices to Western Regional Office are originating with and are counter signed by P.A.D.P. for payment.

   To date, payments have been initiated in the amount of $4,134.00 on this account.

   At this writing, it is difficult to estimate if there will be any change to the final contract amount of $20,000.00.

4. As work proceeded on the rockfill impoundment construction, it became apparent that certain items of work were not covered by the excavation and placing of rock as in a contract described in Item 1 of this summary. It was necessary to employ a contractor to clear a Barge unloading site, provide men and equipment to unload the camp buildings and related equipment, set up the camp buildings in the allotted space, build and install a pontoon landing dock for aircraft in the river channel, provide and install boardwalks as required in the area, dig and maintain a settlement water well, anchor the camp buildings and hoard-in with plywood and insulation, supply and maintain fuel for heating, cooking and diesel fuel for the lighting plant, when the work

is completed to remove the camp buildings to a new location, and to clean up the construction site area restoring all damaged environmental conditions.

In addition to the above, a contractor was required to provide services to administer to the cleanliness of the camp, water system, sewage system, and maintain heating and electrical systems; included also are the installation of culverts with flap gates and a fishway flume. Removal of ice from the river was accomplished by the use of explosives to permit the final placing of rock and rip-rap on the shell zone of the impoundment weir construction. It was found to be necessary to use explosive technique to consolidate dumped rock into the alluvium to obtain maximum density and achieve the design intent of the dam structure. All of these items and many other smaller ones were carried out on a force account basis, the total amount consolidated into a contract of $15,700.00. Payments have been made on this contract in the amount of $14,915.00. This contract will be fully paid to the authorized amount before March 31, 1972.

5. The initial impoundment weir design required that the rockfill work be carried out in two stages. The first was to build a base containing a core and shell zone of sufficient size up to elevation 684'0" to enable the structure to be raised at a later date to a higher elevation as water levels required. The second stage of adding rock to the now existing weir is to be carried out under instructions from the Peace-Athabasca Delta Project who are monitoring water levels in the area. The end result is to raise water levels from existing lows of 683'0" to 688'0" or 690'0" elevation. The necessary segregated rock has been prepared and is waiting in stockpiles to be used.

A contract was prepared to have a contractors' equipment on site during the winter season and spring breakup to permit immediate action when the need for raising the structure was evident from water level readings. To achieve this a rental situation for equipment and personnel was effected in the amount of $7,500.00

6. Ski-Doos

These six ski-doos were purchased under a D.S.S. purchase order for use in the Peace-Athabasca Delta Project of survey work listed as WR159-71.

The total value of this contract is $3,800.00 and is expected to be expended before March 31, 1972.

7. Peace-Athabasca Delta Project

The National and Historic Parks Branch Financial Section is serving as payment vehicle for invoices originating with P.A.D.P. and that are related to the Impoundment Weir construction work. Some of these items include aerial and ground survey controls, rental costs for the support camp, helicopter service, culverts for fish flume, electrical generators and distribution wiring, various types of fuel for the camp, and design consultant fees.

It should be noted that expenditures under this item are not controlled by D.I.A.N.D. and that an end result cannot be accurately forecasted.

SPECIFICATIONS

WEST BRANCH IMPOUNDMENT

QUATRE FOURCHES AREA
ROCK FILL DAM
ENTRANCE TO MAMAWI LAKE FROM LAKE ATHABASCA

PEACE-ATHABASCA-DELTA PROJECT

DESCRIPTION

The work to be done under this contract consists of the construction of a rock fill, end dumped, dam across the West Branch of Chenal Des Quatre Fourches using a mid stream island as an anchor; modification and repair of stream channel banks. including rip-rap protection on the north bank of the access road; and other works as shown on the plans or hereinafter described.

LOCATION

The rock fill, end dumped dam is located on the West Branch of the Chenal Des Quatre Fourches in Wood Buffalo National Park, a distance of approximately 10 miles from Fort Chipewyan, Alberta.

TIME SCHEDULE

(A) Work shall commence on the project within 5 days of notification.

(B) All construction and all backfill channel modifications and rip-rap protection shall be completed by December 11, 1971.

(C) Within one week of notification, the contractor shall submit to the engineer a detailed work schedule outlining the various phases of the work and showing the dates that work on each phase will start and be completed.

AESTHETIC CONSIDERATIONS

The work under this contract is within a National Park, and the contractor shall at all times, conduct his operations in a manner so as to ensure there is no damage or disfigurement of natural features and vegetation immediately adjacent to or outside the construction limits of the project. The cutting of trees or operation of equipment beyond the staked or designated work areas and beyond the approved or designated limits of material sources will not be permitted except with the prior consent of the Engineer, and all environmental damage must be repaired to the satisfaction of the Engineer.

CONSTRUCTION CAMP

Any proposed construction campsite or plant location must be approved in writing by the Wood Buffalo National Park Superintendent.

MATERIALS

Materials used for embankments shall be free from much, wood, brush, roots, sods, ashes, rubbish, top soil and other organic matter and of such quality as required for proper compaction by the methods hereinafter specified. All material shall be approved by the Engineer prior to incorporation.

ROCK MATERIALS AND RIP-RAP

Any rock and rip-rap materials required will be obtained from the following sources:

(A) A Pre-Cambrian Shield rock outcropping on the north bank of the West Branch of Chenal Des Quatre Fourches approximately 600 feet from the north section of the rock filled dam. The use of this source shall be in a manner approved by the Engineer and upon completion of the work

The contractor shall trim and restore the site by replacing top soil to a condition meeting with the approval of the Engineer. The contractor shall be responsible for providing and acceptable restoring necessary access to the site and other work related to supplying the rock and rip-rap materials to the site of the work.

DAM FOUNDATIONS

(A) The foundation for the rockfill dam will not require previous preparation by excavation.

PLACING ROCK FILL AND RIP-RAP EMBANKMENT

(A) End dumping of sorted, excavated material will proceed outward to the main stream channels from the north bank.

(B) Where an embankment is to be constructed on a slope or against an existing river embankment, the sloping surface shall, if required, be benched or scarified in such a manner that the new material will bond with the existing surface. The method employed shall be approved by the Engineer.

(C) The dam shall be constructed to the required cross-section.

(D) The rock fill dam will be composed principally of material obtained from rock cuts. The larger stones shall be carefully distributed and the interstices filled with smaller stones and other material to form a compact mass. Such embankments shall be constructed in layers not exceeding 3 feet. The placing of individual rocks and boulders not exceeding 5 feet in least dimension will be permitted in shell zones provided they are carefully distributed and the interstices filled with finer material to form a dense and compact mass. Each layer, before

starting the next, shall be levelled and smoothed with suitable equipment. Hauling and spreading equipment shall be operated over the full width of each layer.

The top of the rock surface shall be chinked with rock spalls and fines to form an earth-tight surface.

CLASSIFICATION

(A) Excavation Rock for rock fill dam and rip-rap

Excavation Rock means:

I) Material excavated from solid masses of igneous or metamorphic rock which, prior to removal, was integral with the parent mass; and

II) Boulder or rock fragments measuring in volume 2 cu. yds. or more.

(B) Excavation Common

Excavation Common shall comprise the excavation of all other materials of whatever nature, including alluvium, dense tills, hardpan and frozen materialsthat do not come under the classification of Excavation Rock.

UTILIZATION OF EXCAVATED MATERIALS

All suitable materials removed by excavation from the approved source shall be used as far as practicable, in the formation of the rockfill dam.

LOCATION OF SOURCE ROCK

The contractor shall notify the engineer sufficiently in advance of opening any approved borrow areas, so that necessary measurements may by made.

STRIPPING AND WASTE MATERIAL

Material unsuitable for embankment shall be removed to the lateral limits and

depths specified. Upon com pletion of Dam construction, the waste material in windrows shall be blended against the embankment and trimmed to blend with the dam and access road slopes.

Stripping material which, in the opinion of the Engineer, is suitable for top-soiling shall be placed in stockpiles at designated locations.

TOPSOILING

Topsoil material taken from stockpiles or other sources shall be placed at the locations and to the depth as directed by the Engineer. Surface stones, roots, and other debris shall be removed and the surface left in a uniform condition.

TRIMMING

The top surface and side slopes of the embankments shall be left in a neat and workmanlike condition and true to the lines and grades shown in the plans or as staked by the Engineer, where, in the opinion of the Engineer, satisfactory trimming cannot be obtained by mechanical means, hand trimming may be called for.

EXCAVATION

All excavation carried out under this contract shall be classified under one category listed below and shall include the removal and deposition of all excavated material regardless of size, shape or composition.

The contractor is advised that the volume of rock and material rip-rap within the excavation limits as shown on the plans or as staked or designated by the Engineer in the field, will be included in the excavation volume measurement.

Any excavated materials surplus to the staked or designated rock-fill dam requirements shall be acceptably located as additional access road or protection material and stockpiled in other areas as designated by the engineer.

Rock slopes in the borrow areas must be carefully scaled down and all rock, boulders and fragments which are liable to slide or roll down the slopes shall be removed. No rock shall be left projecting within the limits of the staked sections.

DRAINAGE

Side ditches shall be constructed to the depths and widths indicated on the plans, to permit ready run-off of surface water.

FINISHING TOP SURFACES AND SLOPES

The top surface and side slopes of cuts shall be left in a neat condition and true to the lines and grades as staked by the Engineer. When boulders are encountered in cut slopes they shall be removed on the instruction of the Engineer and any resulting cavities shall be filled and thoroughly compacted.

When, in the opinion of the Engineer, satisfactory grading cannot be obtained by mechanical means hand grading may be called for.

OVERHAUL

For the purpose of this contract, there shall be unlimited freehaul on rock and rip-rap excavated materials.

Measurement-Excavated Rock

(A) The quantity of excavated rock for which payment will be made shall be the volume in cubic yards measured in its original position and computed by the average end area method, including boulders 2 cu. yds. or greater in volume, which is acceptable excavated and placed in accordance with these specifications. Boulders or fragments of rock shall be based on measurements only, and the contractor shall give the Engineer opportunity to make the required measurements.

Drilling and shattering will not be measured for payment.

(B) Where, in the opinion of the Engineer, unavoidable overbreak occurs, payment will be made for the actual quantity involved, provided this overbreak quantity does not exceed 10 percent of the actual quantity of rock within the lines as staked by the engineer between the extablished 100 foot station intervals where the overbreak occurs.

DESIGN INTENT

(A) The rockfill dam to be constructed by end dumping of various rock gradings to produce the following characteristics. The core of the dam is to consist of rock containing sufficient fines, such that the final structure will be relatively impermeable. The shell zones are to provide resistance to erosion by water and/or wave action. The fillets at the north abutment of the small channel are to provide resistance to erosion of the alluvial material in the foundation of the north abutment. The contractor must be prepared to adjust his operations both in excavation and placing in accordance with the Engineer's field direction in order that the completed structure will meet the above requirements.

(B) The contractor should be aware that portions of the rockfill dam will be supported on varying depths of alluvium. This alluvium has been found to be up to 40 feet thick and is generally in a soft condition. It is fairly certain that due to the addition of the rock fill, particularly where the fill is thicker than 5 feet, that the silt foundation will partially fail, resulting in appreciable subsidence of the rock fill. During the course of construction it will be mandatory that the contractor's supervision staff and other personnel maintain continous observation of the embankment for evidence of subsidence and to take necessary safety precautions and corrective actions.

(C) Due to the risk of subsidence during construction, it will be necessary that no equipment be left unattended on the embankment even for short intervals. Furthermore the contractor should provide a well-maintained safety boat in the river and provide on the embankment life preservers and other suitable rescue equipment, to be used in the event that equipment operators fall into the river as a result of dam subsidence.

(D) The contractor should be advised that the owner intends to instrument the rockfill dam to assist in assessment of the performance of the dam. The contractor is to assist where necessary in installation of these installations. Settlement markers established on the surface of the rock fill are not to be disturbed or damaged.

(E) The contractor should be aware that provision must be made in the dam to incorporate a structure, yet to be designed, to accommodate passage of fish. The contractor must be prepared to adjust his operations and construct these structures at the direction of the engineer.

ZONING

(A) The contractor shall adjust his operations in blasting, loading and placing to produce the zones shown on the drawings. The rock gradation requirements for each zone are listed below. It is emphasized that these gradations refer to the in-place rock fill in the dam.

(B) Rockfill Zone Gradations

Description	Nominal Rock Size (Inches) % Rock Size Equal to or Less than 90%	50%	15%
Core	24	9	3
Shells	48	24	12*
Spalls	12	5	2

*Amount of fines (i.e. less than 12 inches) shall be such that they do not completely fill the spaces between the large rock pieces.

QUARRYING

(A) Blasting shall be by the bench method.

(B) Initial blasts in the rock quarry shall be sufficiently small to permit adjustments of blast pattern in order that the engineer may properly assess rock sizes and gradation produced by a given blast.

(C) During blasting, the contractor is fully responsible for safety of personnel, equipment, building and safe warning of the public.

LOADING AND DUMPING

(A) The loading of the rock trucks should be done in a selective manner to produce individual loads of a particular class of rock which can be dumped in the correct position. The contractor should have a quarry foreman who will directly supervise loading operation to take best advantage of the

various rock sizes of the blasted rock produced in the quarry.

(B) Dumping should be conducted to reduce segregation of the material to a minimum. Truck loads of dirty rock should be dumped in the core or central portion of the dam, with the intent to have the fines filter down into the coarser rock, as it is moved by the bulldozer. Clean, coarse rock should be dumped nearer the outer shells of the dam.

(C) During dumping trucks should be positioned on the fill so that the load is dumped on the dam, rather than over the end. This will serve to reduce danger of trucks going into the water, and will assist in selective reworking of the material by the dozer on the fill.

PLACING

(A) The contractor should adjust his operations to reduce to a minimum the volumes of snow and/or ice trapped within the fill.

(B) North Abutment Fillet. The spalls zone should be placed for the full width of the abutment and to the thicknesses shown on the cross-section. On completion of spalls placement, the main portion of the dam may proceed to a point beyond the end of the fillet region. Once this has been completed, the spalls zone of the fillet shall be covered by a minimum thickness of four feet of shell material.

(C) Stage I Placing. It is intended that Stage I be constructed with the surface of the fill at or slightly above the existing water level. As the channel is progressively restricted, it may prove necessary to raise the level of the surface of the rock fill.

Core Zone. The bulldozer should be operated to keep all fine rock within the limits of the core zone. The intent is that the fine rock and rock dust will fill the voids between the large rock pieces. Segregation of the material should be

pushed in at the end of the dam, rather than over the end of the dam. The advancing face of the core section should precede the faces of the shell zones by a distance not exceeding 20 feet. (Where there has been a failure in the alluvium in a north-south direction, every effort should be made to survey the extent of the aluvium pushed up in the river bed.) Shell Zones. The dumping and placing operation should be adjusted such that no fines are placed in the outer 6 feet of the shell zones. The intent is to produce a dense rough surface of well-keyed graded rock fragments which will meet the specifications mentioned in zoning part (A). It is pointed out that the boundary between the shell zones and core zones is not as distinct a line as shown on the drawings. It is intended that the two zones transitionally grade from one to the other such that the outer shell contains little or no fines.

(D) Stage II Placing. Stage II will be constructed of zones similar in gradation to that required for stage I. However Stage II must be capped with a minimum of four feet of shell material. The contractor should be aware that it may not be practical to use end dumping methods to place the upper layer of shell material on the crest of the dam. In addition to placing the rock by bulldozer working from dumped stockpiles, it may be necessary to manually rework the rock on the crest of the dam in order to produce the required dense rough surface of well-keyed graded rock fragments which will meet the gradation sizes specified.

BIBLIOGRAPHY

Daily Diary

This document contains daily information from the arrival date of the barges containing the camp and related equipment, the contractor's equipment and fuel supplies on October 9, 1971 to December 10, 1971.

Original diary to be retained on file contains daily summaries of contractor's work, progress, equipment on the job, personnel, and visitors to the site.

Alignment Notes

During the construction period, several small changes in alignment were made as field conditions and design conditions required. The original field book of notes on this subject is being retained on file in Western Regional Office, National and Historic Parks, Calgary.

Original and Final Cross Sections

For purposes of calculation of quantities contained in the access road, the dam proper and the stockpile areas, both original and final levels were taken and recorded. The original field information is contained in a field book being retained on file in Western Regional Office, National and Historic Parks, Calgary.

Record of Water Levels and Dam Settlement

Regular monitoring of rock settlement and water levels was recorded as the rockfill dam construction proceeded. Original field information on this subject is contained in a field book being retained on file in Western Regional Office, National and Historic Parks, Calgary.

Rockfill Dam Stage I (to elevation 684.0)

Cross sections are plotted in detail for planimeter calculation of areas for the North Arm, South Arm, access Haul Road and the rock stockpile. This original roll of information contains areas and the full scope of all cross sections of all the work above described and is kept on file at Western Regional Office, National and Historic Parks.

Quarry - Rock Sections

Full details of the quarry area where the contractor removed rock for the dam construction are recorded for planimeter calculation of the areas. From this roll of detailed cross sections was developed the volume of rock removed by the contractor and the volume of rock upon which payment is made. The original of this roll of cross section paper is kept on file at Western Regional Office, National and Historic Parks, Calgary.

Daily Account Reports

These reports which are on file contain a daily summary of personnel on the job, hours worked by each, cubic yards drilled, cubic yards blasted, cubic yards of rock excavation moved, cubic yards of embankment placed and cubic yards of rock in stock piles. In addition these daily account reports document on a cumulative basis the "down-time" or lost time of the contractor's machinery on the site.

Daily Force Accounts

These reports contain a complete listing of all work that was completed in addition to the contractual requirements.

Weekly Reports

Copies of all relevant progress reports are on file.

Quantity Calculations

Summary sheets showing calculations of rock volumes are on file.

Contractor's Daily Report

Arrangements were made to obtain from the contractor copies of his daily reports to further substantiate the man and equipment operations at the impoundment weir site.

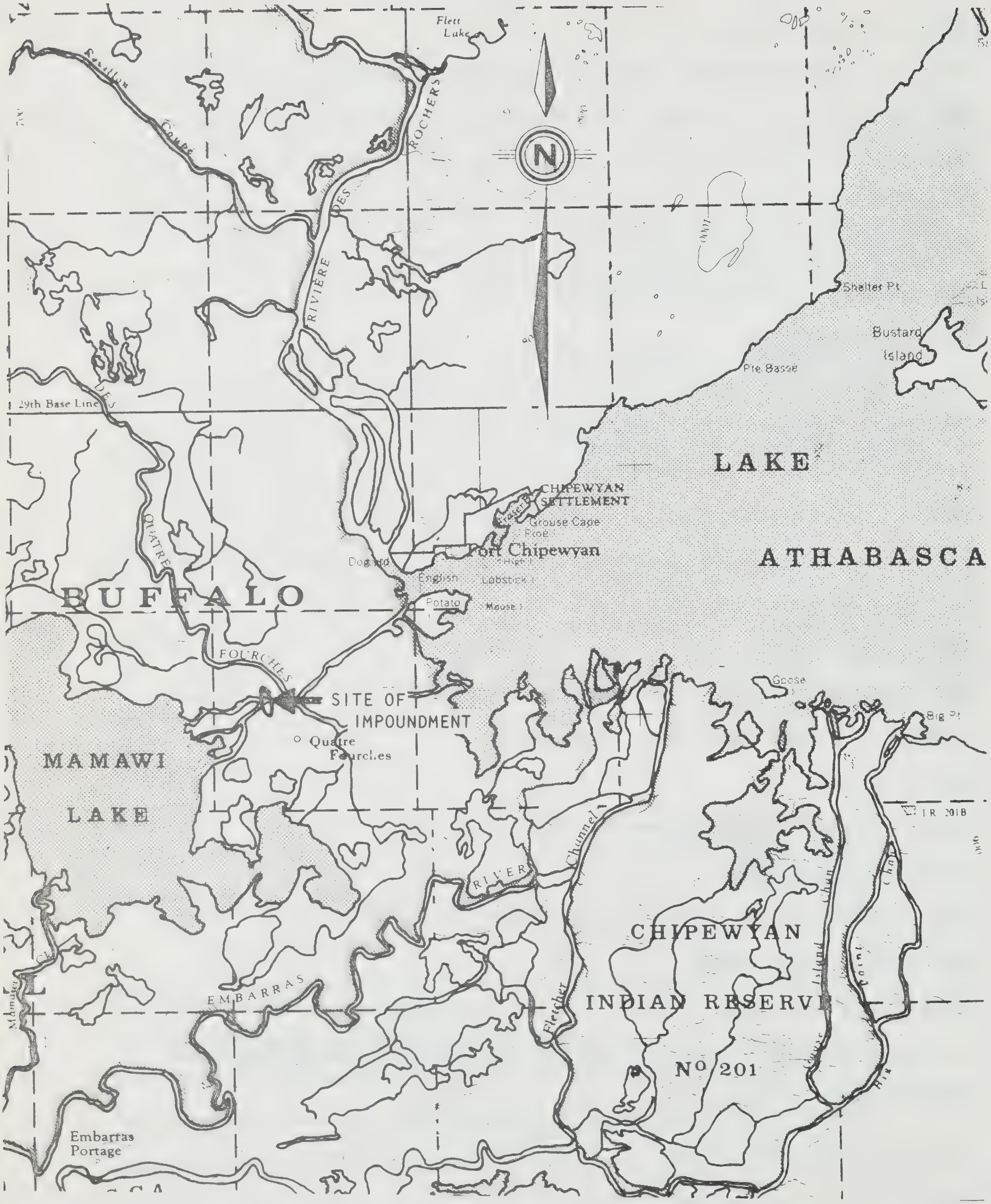
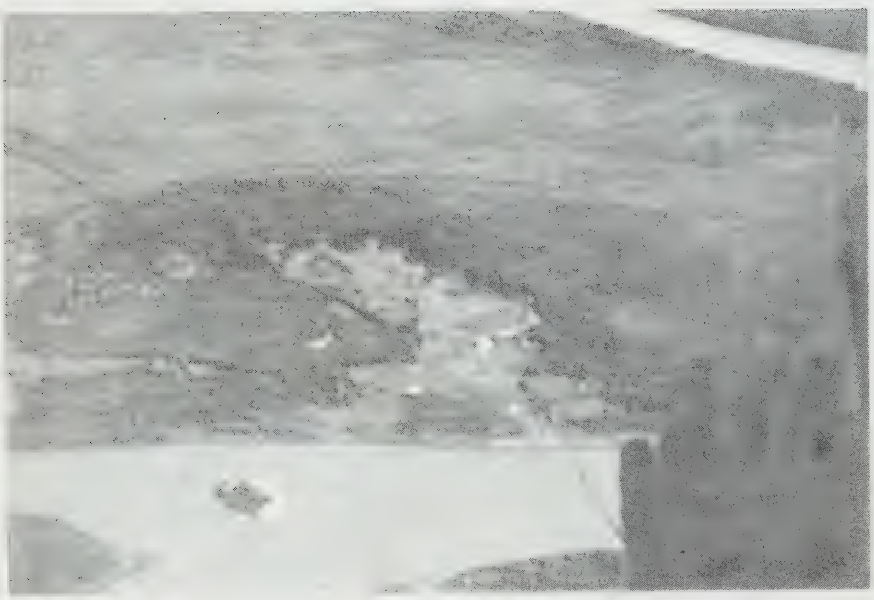


FIGURE 1 Location of the Quatre Fourches Impoundment Structure

PHOTOGRAPH APPENDIX

Original Dam site
looking from east
toward Lake Mamawi.



Original Dam site
including quarry area
looking from south
bank to north bank.

Looking at Quarry
from N. W. to S. E.
end.

October 21, 1971.

Looking at North Dam
from Station 1+90
toward haul road.

October 30, 1971.

Standing at Station
0+00 looking at
Haul Road and Quarry.

October 30, 1971.

Equipment working in
Quarry.

October 30, 1971.

Construction of North
Dam from air.

Date unknown.

Construction of
South Dam from air.
Looking from north-
west to southeast.

Date Unknown.

Construction of South
Dam from air looking
from southeast to
Northwest.

Shell material on Eas
Edge of South Dam

November 29, 1971

Looking at South
Bank from Sta. 4+00

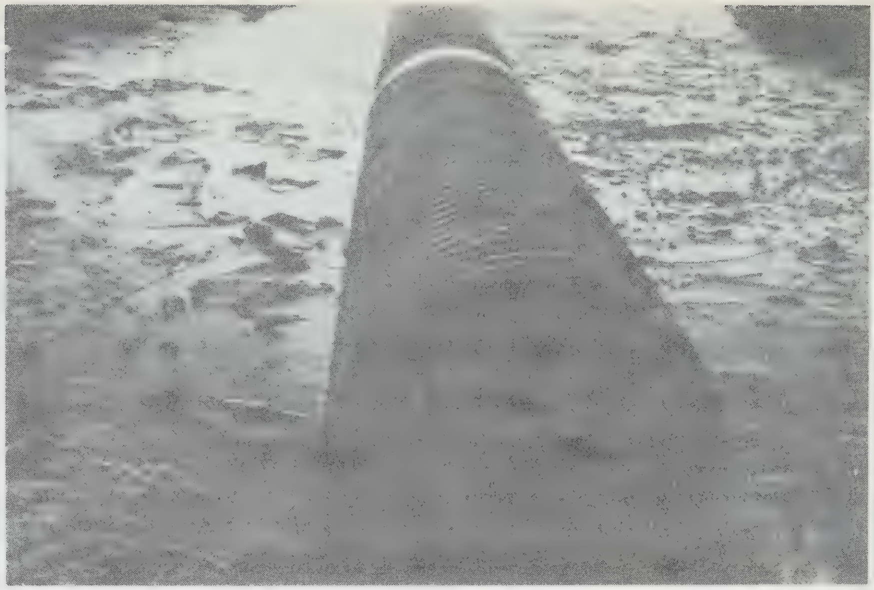
November 29, 1971.

Camp & Quarry sight
from air.

Date unknown

30" culvert in place looking from East to West.

December 5, 1971



Total view of culvert looking from East to West.

December 5, 1971

Blasting ice to remove excess rock from ends of culvert fish sluice.

December, 7, 1971.

SECTION M

SECTION M

NAVIGATION SUB-COMMITTEE

REPORT

TO

THE PEACE-ATHABASCA DELTA STUDY PROJECT

Submitted by:

C.D. Forbes, P.Eng.
Department of Public Works
Representative
Technical Advisory Committee
May, 1972

ABSTRACT

An overview of the role of navigation and problems of low water conditions within the study area and on the Mackenzie River system is presented in terms of the past, present and future. Activities of various agencies and vested interests concerned are mentioned as well as the potential threat to navigation resulting from possible diversions from the Embarras River and a proposed Embarras River-Athabasca River cut-off. Decision criteria on the diversion warranting further consideration is suggested. The effects of water level control within the Peace-Athabasca Delta area to navigation both within the study area and on the Mackenzie River has been examined with particular reference to a proposed ice dam. The conclusion reached is that a dam on the Riviere des Rochers could be highly detrimental to the interests of navigation on Great Slave Lake and the Mackenzie River. Decision criteria and design parameters are laid down for the Athabasca Delta and Lake Athabasca, Lake Athabasca outflow channels, and remedial works.

NAVIGATION SUB-COMMITTEE

REPORT

TO

THE PEACE-ATHABASCA DELTA STUDY PROJECT

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Nav. Appendix No. 4 - Water Routes - Five Charts

Chart No. 1 - Goose Island Channel

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Chart No. 5 - Available Commercial Barge Routes

Appendix No. 5 - Northern Transportation Company Limited - Tonnages

Appendix No. 6 - Great Slave Lake Hydrograph, 1970

Appendix No. 7 - Great Slave Lake Hydrograph, 1970 With Ice Dam

PEACE-ATHABASCA DELTA PROJECT

NAVIGATION SUB-COMMITTEE REPORT

1. Introduction

The formation of sub-committees along lines of functional expertise was advocated by the Study Director in September, 1971. The need for the use of sub-committees became apparent as the volume of data enlarged and the complexities of the problems involved became more sharply defined. The sub-committees would serve as a function of the Technical Advisory Committee and would draw its members principally from that group. The chairman of each sub-committee would normally be a member of the Peace-Athabasca Delta Project staff. The Study Director's proposal was concurred in by the Technical Advisory Committee.

2. Terms of Reference

The Navigation Sub-Committee, using guidelines laid down by the Study Director, set the following terms of reference:

- Determine the existing and future requirements of navigation.
- Express these requirements in terms of lake and river levels.
- Express the requirements in terms of channel widths, wharves, and other structures.
- Give, or arrange to ensure adequate coverage to potential downstream effects on the Mackenzie River system resulting from proposed remedial measures and/or water management usage in the Delta area.
- Determine sites of particular interest to navigation, and if necessary, to advise on the nature of the investigation or data required.

- Assess other ramifications of the need for water as part of the transportation system.
- Submit recommendations for inclusion in the July 1, 1972 Report.

3. Committee Members

The initial members of the sub-committee are noted below:

Mr. J.R. Card - Chairman - seconded to the Study Group staff from the Alberta Water Resources Branch.

Mr. C.D. Forbes - Department of Public Works of Canada - Edmonton.

Mr. D.E. Longley - Department of Public Works of Canada - Edmonton.

Mr. R.H. Smith - Ministry of Transport Ottawa

Alternate Mr. C.J. Laurie - Ministry of Transport - Ottawa.

Mr. H. Dubinsky - Ministry of Transport - Hay River, N.W.T.

Mr. R.M. Bennett - Water Survey of Canada - Calgary

Capt. G. Hampton - Northern Transportation Company Limited - Edmonton.

The following people were contacted by the Sub-Committee through personal appearances or through correspondence:

Mr. Bruce Hunter - Northern Transportation Company Limited - Edmonton.

Mr. A. Coulson - Engineering Hydrology - Environment Canada - Ottawa.

4. Department of Public Works, Canada

.1 Interests

- The Public Works primary interest was in the provision of adequate water depths for the Water Transport Industry, river improvements generally, and the construction of wharves. Their possible secondary interest in the study was that, as a construction agency, they could be called upon to build whatever remedial works, if any, are decided upon. As the Public Works

were carrying out engineering studies on the Mackenzie River with a view towards navigation improvements, they were also interested in any water management practices which were proposed within the Mackenzie River watershed.

- At the commencement of the project study, their initial interest lay within the Athabasca Delta in the present barge navigation track from Mile 183 out into Lake Athabasca and west to Fort Chipewyan, navigation in the Chenal des Quatre Fourches, and upstream as far as Mile 134 on the Athabasca River where the Embarras River leaves the Athabasca. As the project study developed, the Public Works felt that downstream effects on the Mackenzie River resulting from possible water management usage within the Delta was of equal if not greater concern than existing navigational problems within the Delta area.

.2 Dredging

- The Public Works commenced dredging on the Big Point Channel in 1945. The objective of this dredging was to assist in the movement of water borne freight into Lake Athabasca, and also down the Slave River from Lake Athabasca into the Mackenzie River system. Depending on the rate of siltation being experienced in the Delta, and yearly lake levels, the maximum channel provided is 200 feet with a maximum depth of water of 5 feet. From 1958 to 1967 an average of 95,000 cubic yards of material had been dredged per annum from the Big Point Channel. From 1968 to 1971 the yardage removed increased to an average of 201,000 cubic yards per annum for an increase from the previous 10 year average of 106,000 yards per annum. In 1970 the cost chargeable to the

Big Point Channel dredging amounted to $129,700. The dredging is carried out by one 12 inch, and one 10 inch, hydraulic cutter suction pipeline dredges. These dredges also operate periodically at other locations on the Athabasca River upstream from the Delta. From 1968 onwards it has been necessary to work the dredges almost fulltime in the Big Point Channel.

.3 Water Levels

- The Public Works Low Water Datum for dredging purposes in the Athabasca Delta is measured at Geodetic bench mark No. 1700D located at Mile 186.3 from Waterways near a village on the Big Point Channel. At this point the Low Water Datum is taken at elevation 684.47. The attached Nav. Appendix 1 and 2 show readings taken at the Delta gauge in 1971 and at various times in 1966, 1967, 1968, 1969, and 1970. These readings illustrate the gauge relationships between the Athabasca Delta gauge and the Water Survey of Canada gauge at Fort Chipewyan, and the river gradients which can be expected at various lake and river levels. The waterline at Crackingstone Point is noted in order to determine wind set up or draw down at Ft. Chipewyan. Omitting readings taken when wind set up or draw down was excessive it is apparent that the differential in head between the Delta gauge location and the lake would rarely exceed 1.7 feet and at the higher lake level approaches or equals zero. Appendix 3 is at-attached to indicate the apparent shifting which can take place between bench marks, presumably through frost action.
- The data presented in Appendix 1 also indicates that the Low Water Datum shown at Mile 186.3 as 684.47 feet is equivalent to

the navigational Low Water Datum of 683.0 at Fort Chipewyan on Lake Athabasca. Using a cut-off date of October 15 as given by the Northern Transportation Company Limited, and the stage duration curves for a natural water regime provided by the Water Survey of Canada, this Low Water Datum would be equivalent to the 20% curve on October 15, or of water levels equal to lower than 683.0 in one year in five years.

.4 Water Routes

Five maps are attached labelled Nav. Appendix 4 showing the routes that have been travelled commercially by navigation with the Athabasca Delta and the time during which these routes have been used. Map No. 5 indicates the commercial navigation routes on Lake Athabasca, Rivière des Rochers, Chenal des Quatre Fourches, Peace River, and the Slave River going north into the Mackenzie River System. Present barge operations on the Peace River go up to Sweetgrass Landing; in the past they have gone up as far as Red River Post just below Vermilion Chutes. Recreational navigation is of course possible above Vermilion Chutes. These water routes provide the only means of access to the south to the communities around Lake Athabasca, outside of air transport, and a winter road to Ft. Chipewyan. The distance from Waterways, Alberta, to Bushell, Saskatchewan is 273 miles by water with a cost of 7.3 cents per ton mile for class five freight, and 3.3 cents per ton mile for bulk petroleum. These costs include handling and storage at Waterways and unloading at Bushell. It is felt that these rates would be more than competitive with highway transport rates, should highways be provided

in the future, and therefore, navigation plays, and will continue to play for some time in the future, an important factor in the economy of the Lake Athabasca area and the Peace-Athabasca Delta.

5. Ministry of Transport

.1 Interest

- The Ministry of Transport's interests lie in the provision of aids to navigation, such as fixed ranges and buoys for navigation, and the operation and control of public wharves after they have been constructed by the Department of Public Works. The Ministry also controls the placing of structures on navigable waters through the administration of the Navigable Waters Protection Act.

.2 Aids to Navigation

- The Ministry of Transport places navigational aids on the Athabasca River, Athabasca Delta, Peace River, and Rivière des Rochers. The following is their estimation of the problems of additional costs involved through the lowering of lake levels since 1968.
  - The Public Wharf at Fort Chipewyan is no longer accessible to their vessels, with resultant inconvenience in delivering helicopter fuel, navigation aids, etc.
  - Fifteen additional aids have been placed at the Willows Channel where it enters Lake Athabasca with an estimated cost of $725.00 each.
  - Four additional aids have been required at various locations

on Lake Athabasca to indicate shoals now dangerous at low water levels. The cost of these aids is estimated at approximately $725.00 each.

- The water levels in the Chenal des Quatre Fourches River has dropped to the extent that passage of their aids to navigation vessels from the Peace River to Lake Athabasca has proven difficult.
- Lake Athabasca low water levels have caused problems with unloading freight at several areas, principally at the Fort Chipewyan dock. As loaded barges and tugs cannot reach the dock due to shallow water, the commercial carriers have had to put an empty barge on to the end of the dock and ramp up to the dock level. This has caused delays in freight handling and results in additional cost to the carriers over and above handling methods used in the past.
- Commercial amphibian aircraft operators landing on Lake Athabasca in the vicinity of Fort Chipewyan have found that abnormal shallow water conditions and extensive mud flats have made their operations more difficult. These shallow areas have been investigated and no adequate alternate sites to the lake in the vicinity of Fort Chipewyan are available within economical reach.

6. Northern Transportation Company Limited

Northern Transportation Company Limited has provided a chart, attached as Nav. Appendix 5, showing the tonnages carried on the Athabasca System from 1949 to 1971. At one time most of the freight going north

down the Mackenzie River passed through Lake Athabasca and down the Slave River by way of the Peace-Athabasca Delta. As noted on the chart, there is very little freight now going north down the Slave River, and this system has lost most of its commercial importance for traffic into the north. At the present time there is a considerable movement of lumber southward from Sweetgrass Landing on the Peace River. However, the saw-mill which is the source of this lumber will likely be moved to the southern portion of the Delta near the Embarras River and the relocation would virtually eliminate most of the tonnage taken from the Peace River area southward through the Delta.

This would mean that north and south traffic along the Chenal des Quatre Fourches or Rivière des Rochers would be very small. The closure of both rivers to navigation could not however be considered feasible since some traffic will still be necessary in the future to provide the flexibility of operations for water borne traffic between Lake Athabasca and the Mackenzie River.

At this point in time the Company could not provide a precise statement of the future of water borne traffic through the Delta area as there are several uncertainties in the future of the mining industry in Northern Saskatchewan which can be served by water transport from Lake Athabasca. If there were an increase in scale of developments the mining industry would require a considerably larger volume of movement of goods by barge than is presently being carried. If there were adequate navigation facilities which permitted the transportation of large volumes of materials by water transport the bulk of transport of ore or ore concentrates might be a future consideration.

Besides the problems of low water conditions in the Willows Channel area of Big Point Channel in the Athabasca Delta, the Company has also experienced shallow draft problems in the Chenal des Quatre Fourches, principally at the confluence of this river and the Peace River. The problem here was that of shifting sand bars which on low water conditions made barge traffic difficult. The reverse flow conditions at this location shifted the deep water channel from one side to the other. It was considered that dredging would not materially assist in alleviating this problem and that higher water levels and/or river training works would be necessary to overcome the shallow water conditions.

The low water conditions experienced on Lake Athabasca have in effect meant that the Delta area is a critical controlling factor on the draft to which they can load their barges. Whereas in the past they could at times load up to a maximum draft of 5.0 feet under favourable conditions, the continuing low water conditions have cut them back to under 3.5 feet for most of the navigation season. This loss of draft represents very heavy additional operating costs to the Company.

7. <u>Embarras-Athabasca River Cut-off</u>

The information provided by the Project Study Group through their consultants on the probability of a cut-off occurring between the Athabasca and Embarras River is a source of concern to the Sub-Committee. With an average rate of erosion of 35 ft/annum it would appear that a cut-off could develop within a six year period.

The physical scale of this cut-off, and its possible effects on the Delta, are at the time of writing a subject of engineering debate.

The potential effect on navigation through Big Point Channel in the Athabasca Delta is such however as to warrant continuing engineering studies after the completion of the July 1, 1972 report.

It may well be that remedial measures should be undertaken in this area within the next one to two years.

8. Diversions from the Embarras River

The installation of the dam on the Quatre Fourches Channel in 1971 with the objective of increasing the levels of Lake Claire and Lake Mamawi raised the possibility of the need in low flow years to divert water from the Embarras River to maintain the lakes at an optimum level.

There is concern as to the possible effects of such diversion on the water levels in Lake Athabasca assuming no control structures are placed on the Rivière des Rochers. Short term diversion (up to 30 days) would have little effect but long term diversion in a low water year would further reduce lake levels to the extent that an additional dredge may be necessary at the Athabasca Delta to maintain navigation with concommitant heavy capital and operating costs.

Other points warranting consideration are the possible drawdown effects on the upper Embarras River of a 3000 cu. ft. per second diversion. If the river hydraulics are such that a drawdown would occur, channel degradation could be expected followed by increased flow from the Athabasca River to the Embarras River. The latter would be detrimental to navigation on the Athabasca River downstream of the bifurcation of the Athabasca and Embarras River.

9. Downstream Effects of Remedial Works

.1 General

The discussion under this section will deal mainly with the consequences of the proposed ice dam as the hydrology of the dam has been established to a reasonable degree while flexible control structures have not been firmed up to date.

The geographical area of primary concern covers the Slave River, Great Slave Lake, and the Mackenzie River. The period of year in question, i.e., the navigation season, runs from June 3 to October 25. On the Mackenzie River, the river reach which would be strongly affected by lowering spring water levels upstream within the watershed runs from mile 0 at the mouth on Great Slave Lake to mile 203 at the confluence of the Liard and Mackenzie Rivers. The water stages in this river reach are governed principally by the outflow from Great Slave Lake and it is this reach which will be examined in this report. Below the Liard River the spring run-off on the Liard has a mitigating effect on spring low river stages upstream resulting from low stages on Great Slave Lake. The farther downstream you go the flow from other tributaries further masks the undesirable results of low outflow from Great Slave Lake.

As the Slave River carries only light traffic, it is not considered necessary at this point in time to examine navigational problems of low water in June.

.2 Traffic

Approximately 300,000 tons of general and bulk cargo was carried on the Mackenzie River in 1971, most of which originated from the Hay River marine shipping terminal. Around 25,000 tons had an origin - destination on Great Slave Lake itself. Hay River also

serves as the major shipping terminal for the Great Slave Lake fishing industry. All cargo is handled in a shipping season of slightly less than five months. With the expected pipeline construction, cargo figures could jump to 1,000,000 tons per annum. Delays encountered by the need to reduce cargo carrying capacity of barges, or to relay barges through problem areas, due to low water conditions have a significant impact on the ability to carry large volumes over a short period. To illustrate, a barge train containing six barges consisting of series 1500 barges would lose 210 tons of cargo with a draft reduction of one <u>inch</u>. A reduction of one <u>foot</u> would reduce their cargo carrying capacity by a factor of 25%, of 2500 tons out of a potential of 10,000 tons.

Class five cargo is handled at costs of about 4½ cents per ton mile from Hay River to Inuvik over a water distance of 1000 miles including handling and S.I.T. charges. Bulk Petroleum products are carried at under 3 cents per ton mile. Air cargo costs run around 40 cents per ton mile not including handling. When truck transport is available in the future, rates could be expected to be over double the water transport rate and would not include handling costs. In this light, water transport could be expected to continue to play a vital part in the transportation picture of the Western Canadian Arctic.

.3 <u>Overview of Problem Areas</u> - Four major problem areas can be identified on the Mackenzie River reach in question insofar as water cargo transport is concerned. These are the Beaver Lake area mi. 0-28, the Providence Rapids area mi. 37-45, the Mills

Lake area mi. 68-72, and the Green Island Rapids area mi. 185-202. Great Slave Lake contains the fifth problem area in the channel leading into Hay River, N.W.T. Yearly maintenance dredging is carried out on the Hay River channel.

Where ferry operations are concerned one problem area is encountered near mi. 40 on the Mackenzie River in the vicinity of Fort Providence. The ferry serves as a link in the highway between Hay River and Yellowknife, N.W.T. Ferry operations extend over a much longer season than water cargo transport operations as they commence approximately two weeks earlier and operate around one month later in the fall than the latter. The critical limiting depth for the ferry operation is presently 4 feet.

With a barge draft of 6 feet and a tug draft of 5.3 feet, the water transport industry require a water depth of 8 feet (8.5 feet from mi. 0-2 on the Mackenzie River) for safe efficient operations and proper steerage control over the navigation season. The critical limiting depth in the river reach is 5 feet at Low Water Datum.

.4 Low Water Datum Settings

For purposes of potential major river improvement works by way of dredging, the 10% stage duration curves have been selected as one design parameter. This allows the possibility of water levels being less than or equal to the Low Water Datum in one year in ten. For any one year a maximum fluctuation of water levels during the navigation season of 1.5 feet in Great Slave Lake and 3.0 feet at Fort Providence could be expected; the normal fluctuation would be in the order of 1.0 feet and 2.0 feet. In low water years

therefore you have little choice in your adjustment of barge drafts and are committed to reduced drafts for practically the entire season. Because of extensive shoal areas near a grade depth of 8.0 feet below Low Water Datum, any lowering of the datum would significantly increase dreding quantities. As noted under the following subsection 5, this may be necessary if the ice dams are placed every five years.

.5 Hydrograph Comparisons

Mr. A. Coulson of Engineering Hydrology has prepared two hydrograph charts of Great Slave Lake to our requirements. We have plotted on these charts the minimum 10%, 25%, and 50% stage duration curves developed by R.M. Bennett, Water Survey of Canada, Calgary, for the Public Works of Canada and the navigation Low Water Datum set by Public Works. The stage duration curves developed from long term records illustrate the relationship of the Low Water Datum to possible water stages, and the actual and/or estimated stages to the probability of their occurrence. These charts are attached as Nav. App. 6 and 7. The following should be noted:

- The actual stage shown is that occurring in 1970 with the reservoir filling behind the Bennett Dam in British Columbia.
- The natural stage (estimated) shown is that which would have occurred if the Bennett Dam were not in place. Note it compares closely with the 25% stage duration curve and therefore the 1970 inflows, while below median, were not lower low water flows in the watershed.
- The regulated by Bennett Dam stage is the estimated stage which

would have occurred assuming the Bennett Dam reservoir had been filled sometime prior to 1970 and the generating units and spillway were in operation. Note there is a negative shift of approximately 0.2 feet from the estimated natural stage over most of the navigation season. From this we suspect that the stage duration curves developed from future data will show a negative shift in relation to those developed prior to the Bennett Dam. This is indicative of the long term consequences of the Bennett Dam, insofar as navigation is concerned.

- On App. 7 the regulated by Bennett Dam stages with 100% and 90% storage of local inflow to Lake Athabasca by using an ice dam assumes the Bennett Dam reservoir filled as noted previously for the regulated by Bennett Dam stage alone. Of interest is the information that the ice dam storage for January 1 to June 30 with an impoundment of approximately 19,000,000 acre feet is close to 85% of the annual impoundment behind Bennett Dam while the reservoir was filling.
- With the ice dam in place the water levels would have been below those normally expected i.e., regulated by Bennett Dam stage only, up to around August 20, after which the levels will run approximately 0.2 - 0.25 feet above. By June 1 the ice dam would have lowered levels 0.55 feet, by June 30, 0.73 feet. If the inflows into Great Slave Lake compare with the 10% stage duration curve the ice dam would keep levels below the navigation Low Water Datum until July 25. Such levels would prevent the use of large tugs if dredging is not carried out.

- In 1970, using the regulated by Bennett Dam stage only as a reference base, such an ice dam would have resulted in a net cargo loss of 9000 tons based on the operation of one barge train of six 1500 series barges and water level fluctuations at Ft. Providence. A minimum of three such barge trains would have been in operation for a total net loss of 27000 tons.
- Ferry operation at Ft. Providence in 1970 from May 15 to July 10 would have been hampered with an ice dam installation. If the inflows had been in the 10% stage duration range the ferry would have been inoperative, for all practical purposes from May 15 to near July 25. The extra running time gained in November in sub-zero temperatures would not offset the long delay at the start of the season in good weather.
- Low spring water levels will increase the probability of ice jamming at the mouth of the Mackenzie River on ice break' up on Great Slave Lake. The ice jams can substantially drop water levels at Ft. Providence for period up to six days and halt ferry operations.
- The suspected negative shift in the stage duration curves resulting from the Bennett Dam operations coupled with ice dam installations once every 5 years will likely require a reassessment of the assumed navigation Low Water Datum and a setting at a lower level.

10. Decision Criteria

.1 Athabasca Delta and Lake Athabasca

- Navigation plays, and will continue to play for some time in future, an important factor in the economy of the Lake

Athabasca area, and the Peace-Athabasca Delta.

- Low lake levels have caused problems to navigation and to those agencies responsible for maintaining navigation.
- To assess the long term effects of the Bennett Dam on navigation it will be necessary to develop new stage duration curves for Lake Athabasca and assess the phase shift against former water regimes.
- The cut-off developing between the Athabasca and Embarras Rivers warrants further engineering study as it could have adverse effects downstream on the Athabasca River and Richardson Lake.
- The possible diversion of water from the Embarras River into Lake Mamawi should be studied in terms of: period and time of year of the diversion; maximum total volume of diversion; its effect on Lake Athabasca levels; drawdown effect on the "upper" Embarras from the diversion of 3000 c.f.s. from the "lower" Embarras; the possible channel degradation resulting from the drawdown on the "upper" Embarras River with concommitant increase in diversion from the Athabasca River; and possible lowering of water stages below mile 136 on the Athabasca River should there be an increase in diversion from the Athabasca River.
- Based on past relationships water levels of benefit to the ecology would in most years meet to a large degree the needs of navigation.
- Siltation and channel meander studies in navigation routes could be considered.

- Controlled colour and infra-red aerial photography would precisely define water and channel boundaries and suspended sediment patterns.
- Where a conflict would arise between controlled Lake Athabasca levels for navigational purposes and undesirable downstream effects on navigation, the latter should govern policy decisions.

.2 Lake Athabasca Outflow Channels

- Commercial navigation is active at the present time in the Chenal des Quatre Fourches and the Rivière des Rochers. It is expected, however, that commercial water borne cargo in this area in the future will be very small.
- The Slave River has now lost most of its commercial importance for water transport into the north.
- The closure of both the Quatre Fourches and the Rivière des Rochers to navigation should not be considered, and at least one route should be available to navigation.
- Any structure placed on the Slave River should provide for navigation.
- Shifting sand bars at low water stages are a hazard at the confluence of the Quatre Fourches and Peace Rivers. Dredging would not be a solution to this problem. If the Rivière des Rochers is blocked by remedial works an engineering study should be made of the bar formation to determine if river training works would provide a solution and be economically feasible.

.3 Remedial Works

- The proposed ice dam on the Rivière des Rochers would be highly detrimental to the interests of navigation on Great

Slave Lake and the Mackenzie River.

- When considering moderating the downstream effects of remedial works, recognition should be given to the varying inflows from separate regions of the greater Mackenzie Watershed in order to fully utilize the total available water regime to meet the needs of both the ecological and navigational environment.
- Hydrographs developed from proposed remedial works should be assessed against stage duration curves on both Lake Athabasca and Great Slave Lake. New curves may be required for Great Slave Lake and will be a definite requirement for Lake Athabasca.
- Locks would not be a requirement for a structure placed on the Rivière des Rochers provided navigation is assured on the alternate route through the Chenal des Quatre Fourches and the Peace River down to the Slave River.
- Locks would be a requirement for a structure placed on the Slave River.

11. <u>Design Parameters</u>

.1 <u>Athabasca Delta and Lake Athabasca</u>

- Low water elevation for navigation purposes should be taken as elev. 683.0 at Ft. Chipewyan, and elev. 684.47 at mile 186.3 on the Athabasca River opposite G.S.C. B.M. No. 1700D, using a navigation start date of May 10 and cut-off of October 15 based on a 20% stage duration curve.
- Based on a maximum tug draft of 3.0 feet, and barges loaded to 3.5 feet draft <u>when low water conditions prevail</u>, the water

transport industry requires 5.0 feet of water below Low Water Datum with the controlling factor being tugs proceeding upstream. Maximum barge draft possible at higher water stages is 5.0 feet.

- A 200 foot wide channel should be maintained at the mouth of the Athabasca Delta.
- The 20% stage duration curve would be acceptable only one year in five years due to the heavy siltation rate in the Big Point Channel at low water levels. Normally levels following the 50% stage duration curve would be the minimum required.
- Any diversion from the Athabasca River, whether through natural or artificial means, which would lower river stages below the before mentioned criteria would not be acceptable.

.2 Lake Athabasca Outflow Channels

- Tug and barge draft criteria in the outflow channels should be the same as that specified for Lake Athabasca and the Athabasca Delta.
- If the above criteria is met, and channel siltation is not a factor, a rise of 1.5 feet in water stage from spring to mid July and a corresponding fall to mid October would be acceptable.
- Channel widths would be dependant on speed and direction of current, degree of curvature and total angle turned in bends. A minimum channel width would be 100 feet.

.3 Remedial Works

- The downstream effect of remedial works can only be assessed by routing flows downstream through each individual proposed

structure over a minimum period of one year assuming certain Great Slave Lake elevations at the start. Downstream flows with ice cover both in the Slave River and at the mouth of the Mackenzie could receive further study to arrive at more precise open water stages in the spring.

- Any navigation locks installed should be capable of providing 6.0 feet of water over the sill and accommodating one barge 56 feet by 250 feet long.

LAKE ATHABASCA WATER LEVELS 1971

DATE		GAUGE DELTA	W. L. GAUGE 0.0 =684.47	GAUGE FT. CHIP.	W. L. FT. CHIP. GAUGE 0.0 =682.97	W. L. CRACKINGSTONE POINT	DIFF. FT. CHIP. FROM DELTA	DIFF. CRACKINGSTONE POINT FROM DELTA
1971								
June	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10	0.8	685.27	+1.14	684.11	684.05	-1.16	-1.22
	11	0.8	685.27	+1.19	684.16	684.05	-1.11	-1.22
	12	0.9	685.38	+0.88	683.85	684.04	-1.53	-1.34
	13	0.9	685.38	+1.11	684.08	684.06	-1.30	-1.32
	14	1.2	685.67	+1.67	684.64	684.00	-1.03	-1.67
	15	1.4	685.87	+1.97	684.94	683.95	-0.93	-1.92
	16	1.4	685.87	+1.77	684.74	684.03	-1.13	-1.84
	17	1.4	685.87	+1.45	684.42	684.12	-1.45	-1.75
	18	1.2	685.67	+1.67	684.64	684.15	-1.03	-1.52
	19	1.1	685.57	+1.57	684.54	684.19	-1.03	-1.38
	20	1.1	685.57	+1.42	684.39	684.26	-1.18	-1.31
	21	1.5	685.97	+1.56	684.53	684.31	-1.44	-1.66
	22	1.5	685.97	+1.88	684.85	684.36	-1.12	-1.61
	23	1.4	685.87	+2.35	685.32	684.40	-0.55	-1.47
	24	1.5	685.97	+2.33	685.30	684.48	-0.67	-1.49
	25	1.3	685.77	+2.45	685.42	684.54	-0.35	-1.23
	26	4.3	688.77	+4.17	687.14	684.32	-1.63	-4.45

LAKE ATHABASCA WATER LEVELS 1971

DATE		GAUGE DELTA	W. L. GAUGE 0.0 =684.47	GAUGE FT. CHIP.	W. L. FT. CHIP. GAUGE 0.0 =682.97	W. L. CRACKINGSTONE POINT	DIFF. FT. CHIP. FROM DELTA	DIFF. CRACKINGSTONE POINT FROM DELTA
	27	2.3	686.77	+2.51	685.48	684.59	-1.29	-2.18
	28	2.0	686.47	+1.77	684.74	684.79	-1.73	-1.68
	29	2.0	686.47	+2.05	685.02	684.83	-1.45	-1.64
	30	1.9	686.37	+2.02	684.99	684.85	-1.38	-1.52
	31							
1971								
July	1	1.8	686.27	+2.03	685.00	684.90	-1.27	-1.37
	2	1.9	686.37	+2.19	685.16	684.94	-1.21	-1.43
	3	2.2	686.67	+2.41	685.38	684.98	-1.29	-1.69
	4	2.1	686.57	+2.26	685.23	685.07	-1.34	-1.50
	5	2.3	686.77	+2.51	685.48	685.13	-1.29	-1.64
	6	2.2	686.67	+2.59	685.56	685.18	-1.11	-1.49
	7	2.6	686.07	+2.61	685.58	685.16	-1.49	-1.91
	8	2.3	686.77	+2.42	685.39	685.26	-1.38	-1.51
	9	2.3	686.77	+2.51	685.48	685.31	-1.29	-1.46
	10	2.4	686.87	+2.71	685.68	685.33	-1.09	-1.44
	11	2.5	686.97	+2.58	685.55	685.38	-1.42	-1.59
	12	2.3	686.77	+2.38	685.35	685.47	-1.42	-1.30
	13	2.5	686.97	+2.43	685.40	685.47	-1.57	-1.50
	14	2.5	686.97	+2.61	685.58	685.51	-1.38	-1.46
	15	3.0	687.47	+3.25	686.22	685.50	-1.25	-1.97
	16	2.8	687.27	+3.13	686.10	685.58	-1.17	-1.69
	17	2.8	687.27	+3.05	686.02	685.76	-1.25	-1.51
	18	3.1	687.57	+3.23	686.20	685.92	-1.37	-1.65
	19	2.9	687.37	+3.28	686.25	686.10	-1.12	-1.27

LAKE ATHABASCA WATER LEVELS 1971

DATE		GAUGE DELTA	W. L. GAUGE 0.0 =684.47	GAUGE FT. CHIP.	W. L. FT. CHIP. GAUGE 0.0 =682.97	W. L. CRACKINGSTONE POINT	DIFF. FT. CHIP. FROM DELTA	DIFF. CRACKINGSTONE POINT FROM DELTA
	20	3.3	687.77	+3.51	686.48	686.22	-1.29	-1.55
	21	3.6	688.07	+3.70	686.67	686.30	-1.40	-1.77
	22	3.3	687.77	+3.89	686.86	686.35	-0.91	-1.42
	23	4.9	689.37	+3.26	687.23	686.39	-2.14	-2.98
	24	3.7	688.17	+3.73	686.70	686.52	-1.47	-1.65
	25	3.8	688.27	+3.67	686.64	686.60	-1.63	-1.67
	26	3.3	687.77	+3.95	686.92	686.59	-0.85	-1.18
	27	3.6	688.07	+3.84	686.81	686.60	-1.26	-1.47
	28	3.9	688.37	+3.84	686.81	686.58	-1.56	-1.79
	29	3.3	688.77	+3.58	686.55	686.63	-1.22	-1.14
	30	3.6	688.07	+3.60	686.57	686.58	-1.50	-1.49
	31	3.3	687.77	+3.73	686.57	686.56	-1.07	-1.21
1971 Aug.	1	+3.3	687.77	+3.77	686.74	686.52	-1.03	-1.25
	2	+3.0	687.47	+3.66	686.63	686.52	-0.84	-0.95
	3	+3.2	687.67	+3.53	686.50	686.53	-1.17	-1.14
	4	+3.2	687.67	+3.50	686.47	686.51	-1.21	-1.16
	5	+3.1	687.57	+3.83	686.80	686.39	-0.77	-1.18
	6	+3.5	687.97	+3.42	686.39	686.45	-1.58	-1.52
	7	+3.5	687.95	+3.59	686.56	686.38	-1.39	-1.57
	8	+3.1	687.57	+3.18	686.15	686.39	-1.42	-1.18
	9	+3.0	687.47	+3.26	686.23	686.34	-1.24	-1.13

LAKE ATHABASCA WATER LEVELS 1971

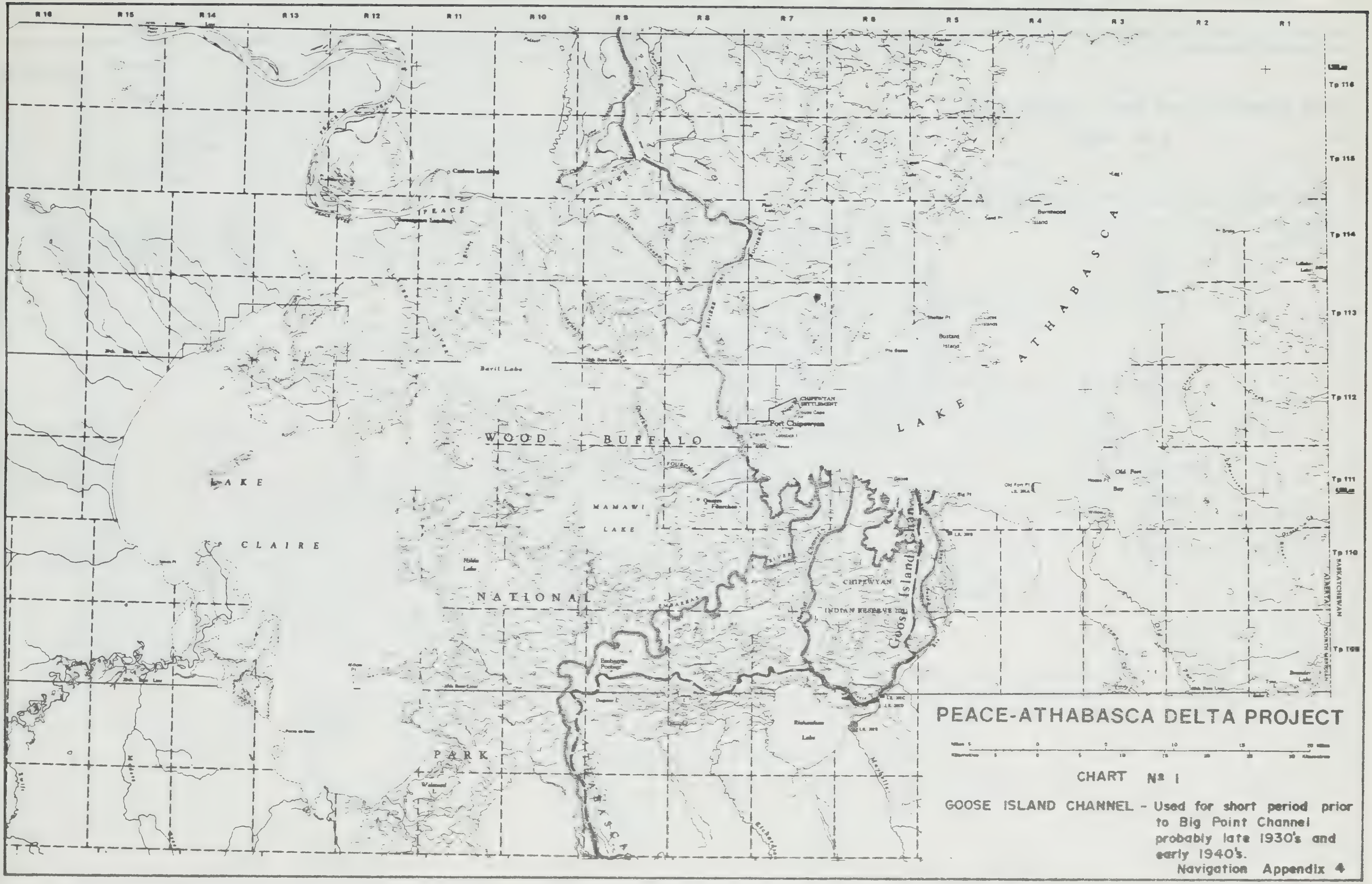
DATE	GAUGE DELTA	W. L. GAUGE 0.0 =684.47	GAUGE FT. CHIP.	W. L. FT. CHIP. GAUGE 0.0 =682.97	W. L. CRACKINGSTONE POINT	DIFF. FT. CHIP. FROM DELTA	DIFF. CRACKINGSTONE POINT FROM DELTA
10	+3.1	687.57	+3.31	686.28	686.29	-1.29	-1.28
11	+3.4	687.87	+3.24	686.21	686.25	-1.66	-1.62
12	+3.4	687.87	+3.27	686.24	686.14	-1.63	-1.73
13	+2.5	686.97	+2.75	685.72	686.26	-1.25	-0.71
14	+3.1	687.57	+3.28	686.25	686.09	-1.32	-1.48
15	+3.4	687.87	+3.64	686.61	685.95	-1.26	-1.92
16	+2.8	687.27	+3.27	686.24	685.95	-1.03	-1.32
17	+3.0	687.47	+3.02	685.99	685.92	-1.48	-1.55
18	+3.0	687.47	+3.01	685.98	685.89	-1.49	-1.58
19	+3.0	687.47	+3.10	686.07	685.84	-1.40	-1.63
20	+3.0	687.47	+3.20	686.17	685.73	-1.30	-1.74
21	+3.0	687.47	+3.05	686.02	685.68	-1.45	-1.79
22							
23	+1.5	685.97	+2.38	685.35	685.78	-0.62	-0.19
24	+2.3	686.77	+2.42	685.70	685.70	-1.38	-1.07
25	+2.1	686.44	+2.44	685.41	685.65	-1.16	-0.92
26	+1.9	686.37	+2.27	685.24	685.64	-1.13	-0.73
27	+2.1	686.57	+2.50	685.47	685.55	-1.10	-1.02
28	+2.3	686.77	+2.50	685.47	685.50	-1.30	-1.27
29							
30							
31							

LAKE ATHABASCA WATER LEVELS 1966-1970

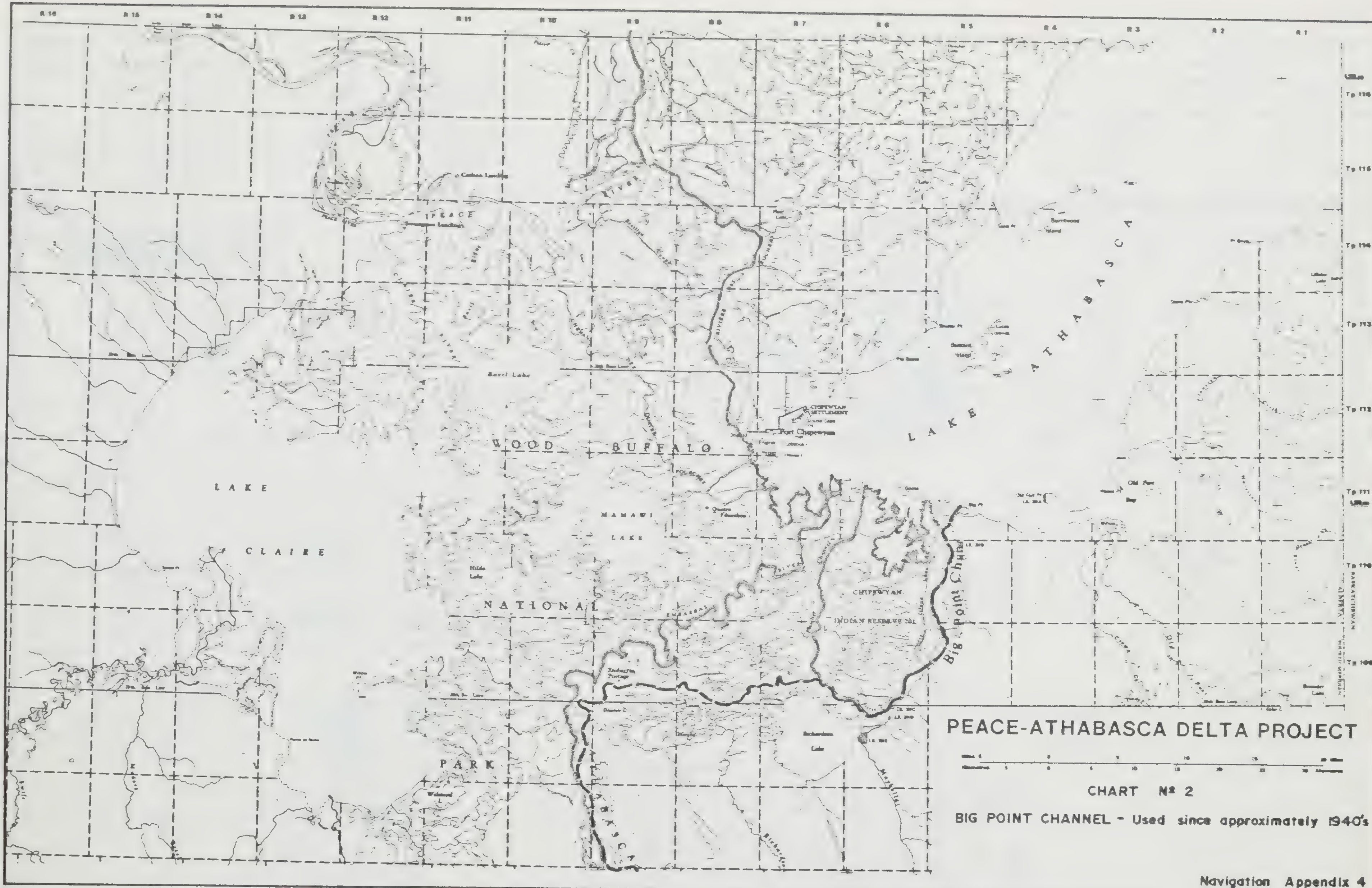
DATE	GAUGE DELTA	W. L. GAUGE 0.0 =684.47	GAUGE FT. CHIP.	W. L. FT. CHIP. GAUGE 0.0 =682.97	W. L. CRACKINGSTONE POINT	DIFF. FT. CHIP. FROM DELTA	DIFF. CRACKINGSTONE POINT FROM DELTA
June 7/66	+2.67	687.14	+3.67	686.64	686.56	-0.50	-0.58
June 10/66	+4.03	688.50	+3.85	686.82	686.78	-1.68	-1.72
June 11/66	+2.93	687.40	+3.96	686.93	686.84	-0.47	-0.56
June 14/66	+3.04	685.71	+4.17	687.14	687.13	-0.37	-0.38
June 17/66	+2.71	687.18	+4.84	687.81	687.38	+0.63	+0.20
June 21/66	+2.79	687.26	+4.40	687.37	687.88	+0.11	+0.62
June 22/67	+5.62	690.09	+6.85	689.82	689.62	-0.27	-0.47
July 5/67	+6.36	690.83	+7.58	690.55	690.54	-0.28	-0.29
July 8/67	+6.32	690.79	+8.00	690.97	690.54	+0.18	-0.25
Aug. 8/67	+5.12	689.59	+6.63	689.60	689.60	+0.01	+0.01
Aug. 9/67	+5.12	689.59	+7.09	689.56	689.57	-0.03	-0.02
Aug. 10/67	+4.93	689.40	+6.84	689.81	689.54	+0.41	+0.14
June 5/68	+1.04	685.51	+1.18	684.15	683.96	-1.36	-1.55
Sept 25/68	+0.36	684.83	-0.28	682.69	683.05	-2.14	-1.78
May 24/69	+1.74	686.21	+3.16	686.13	686.13	-0.08	-0.08
June 10/69	+1.68	686.15	+3.18	686.15	686.15	0.00	0.00
July 17/69	+1.70	686.17	+1.86	684.83	684.63	-1.34	-1.54
Sept 9/69	-0.29	684.18	0.00	682.97	683.09	-1.21	-1.09
May 28/70	+0.84	685.31	+1.01	683.98	683.70	-1.33	-1.61
July 16/70	+1.72	686.19	+1.88	684.85	684.78	-1.34	-1.41

ATHABASCA DELTA BENCH MARK READING
1967-1971

B. M.	ELEV.	DEPARTMENT	YEAR
1700D	0.00		
1701D	+2.17	D.P.W.	1967
1702D	+2.06		
1700D	0.00		
1701D	+2.27	D.P.W.	1968 (Rev. 1)
1702D	+2.14		
1700D	0.00		
1701D	+2.00	D.P.W.	1969
1702D	+2.09		
1700D	0.00		
1701D	+2.00	Peace Athabasca	1971
1702D	+1.95	Delta Project	



PEACE-ATHABASCA DELTA PROJECT
CHART Nº 1
GOOSE ISLAND CHANNEL - Used for short period prior to Big Point Channel probably late 1930's and early 1940's.
Navigation Appendix 4
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
WOOD BUFFALO NATIONAL PARK
PEACE RIVER
ATHABASCA
CHIPEWYAN INDIAN RESERVE
Goose Island Channel
Fort Chipewyan
CHIPEWYAN SETTLEMENT
Bustard Island
Old Fort Bay
Baril Lake
Richardson Lake
Embarras Portage
Carlson Landing
SASKATCHEWAN
ALBERTA
FOURTH MERIDIAN
R 16
R 15
R 14
R 13
R 12
R 11
R 10
R 9
R 8
R 7
R 6
R 5
R 4
R 3
R 2
R 1
Tp 116
Tp 115
Tp 114
Tp 113
Tp 112
Tp 111
Tp 110
Tp 109

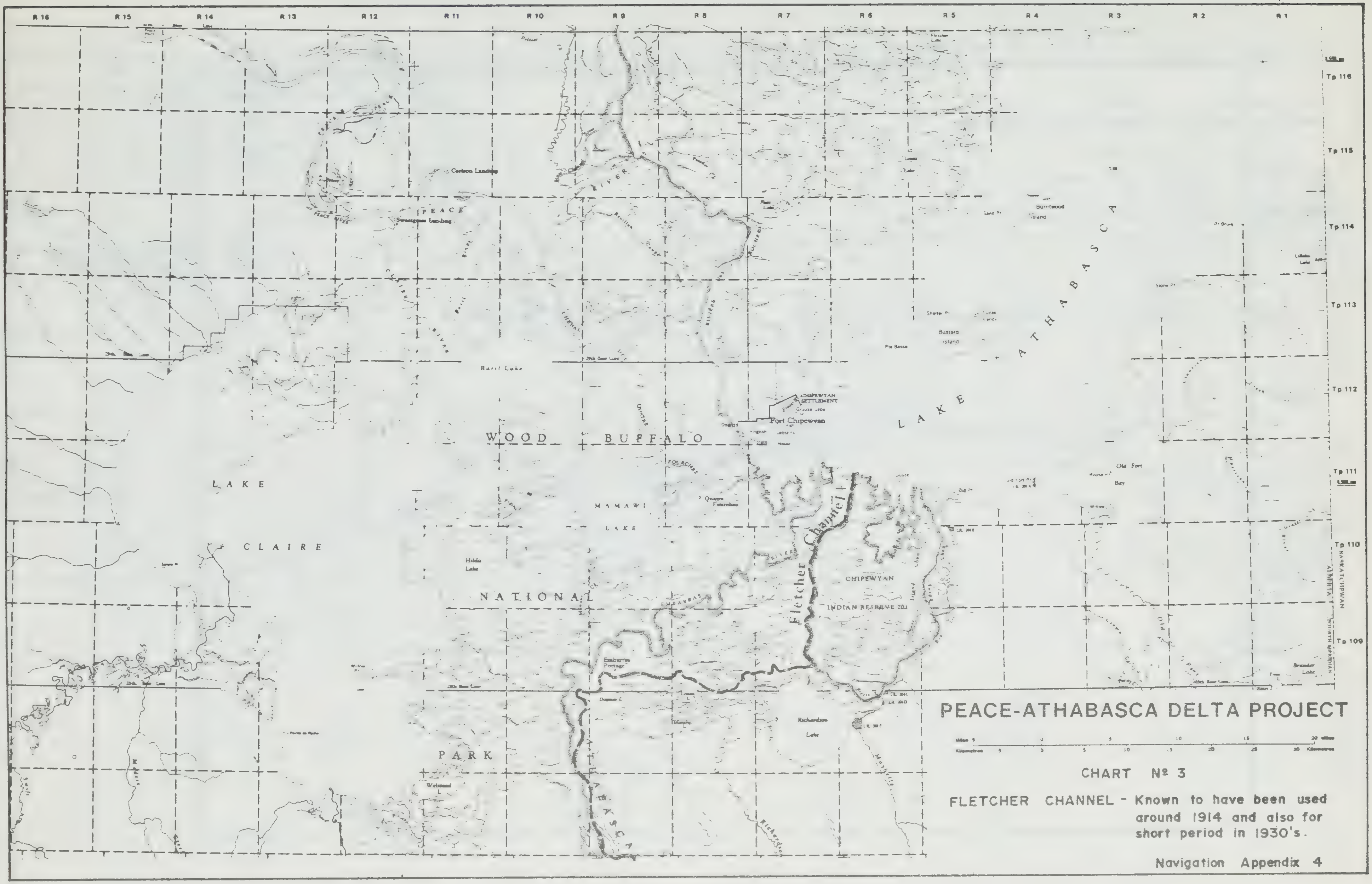


PEACE-ATHABASCA DELTA PROJECT

CHART № 2

BIG POINT CHANNEL - Used since approximately 1940's

Navigation Appendix 4

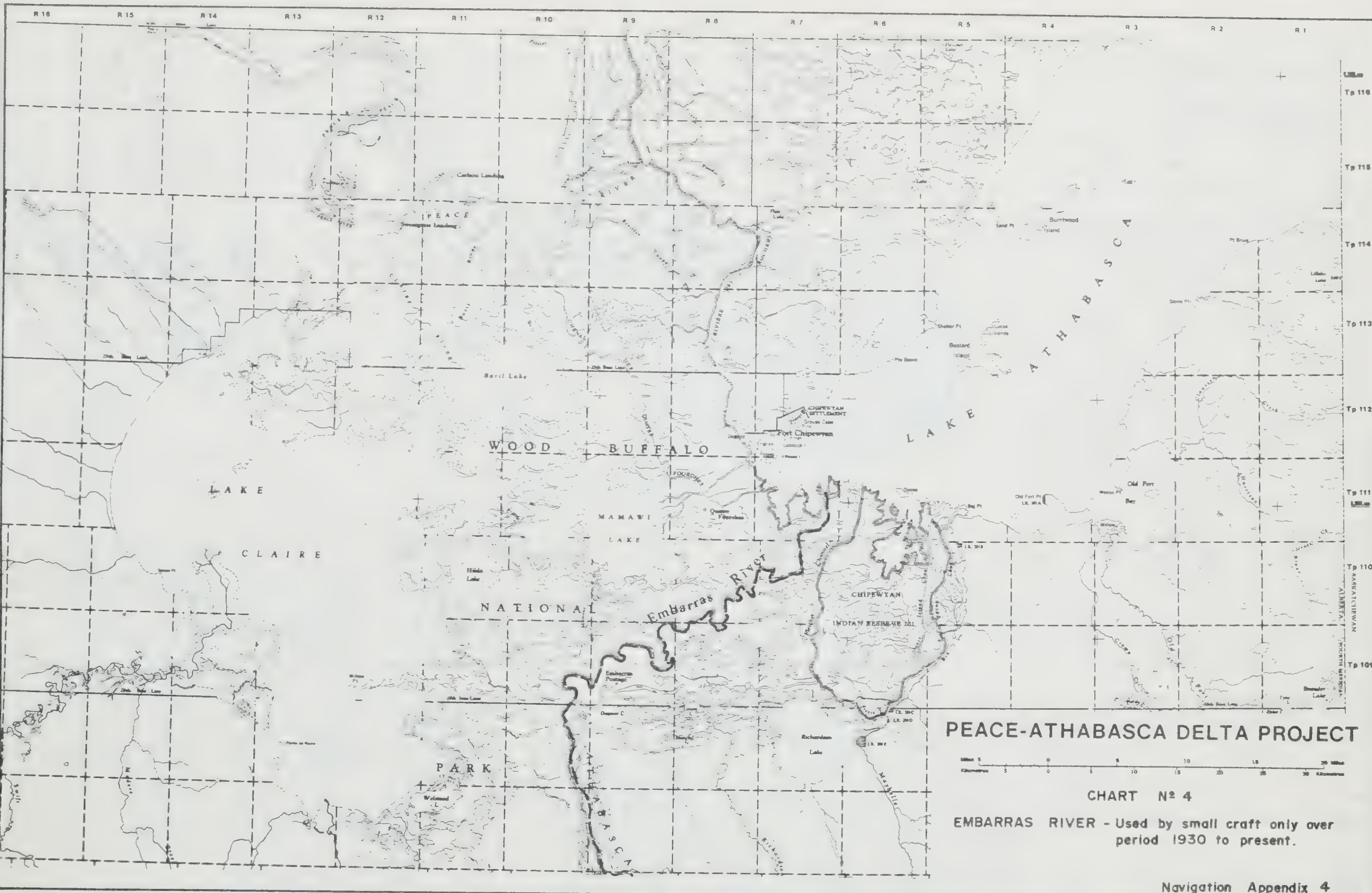


PEACE-ATHABASCA DELTA PROJECT

CHART № 3

FLETCHER CHANNEL - Known to have been used around 1914 and also for short period in 1930's.

Navigation Appendix 4



PEACE-ATHABASCA DELTA PROJECT

CHART Nº 4

EMBARRAS RIVER - Used by small craft only over period 1930 to present.

Navigation Appendix 4

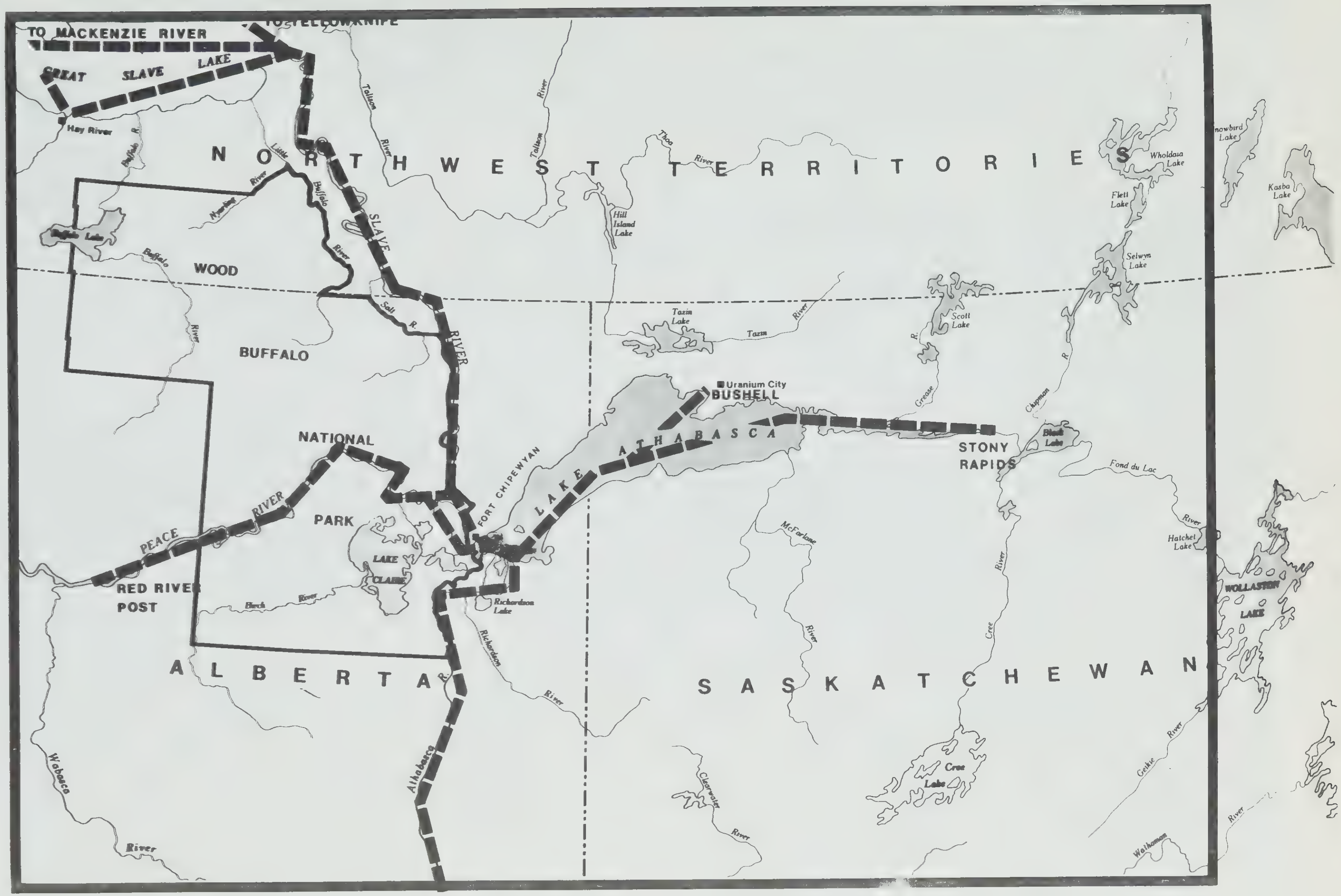
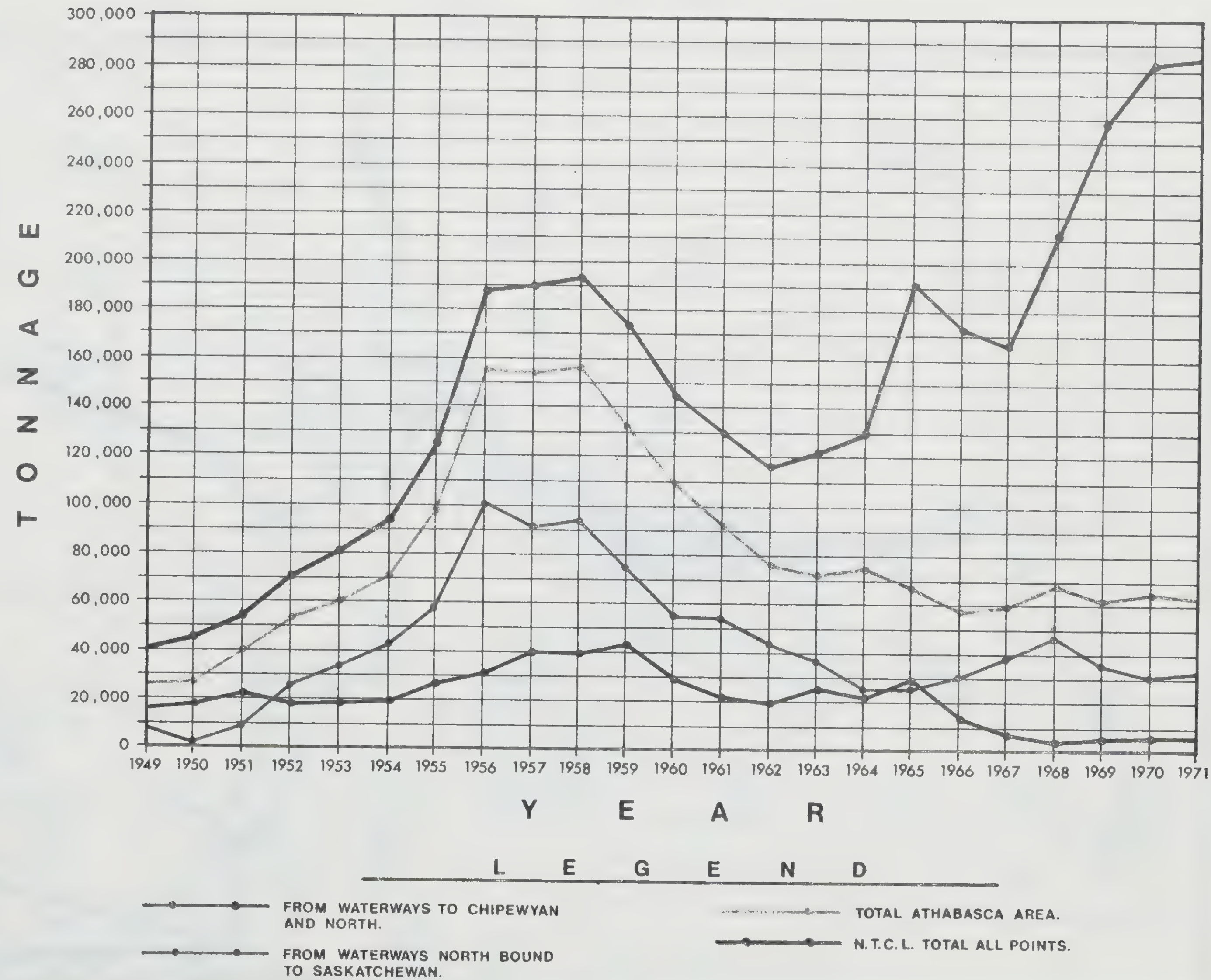
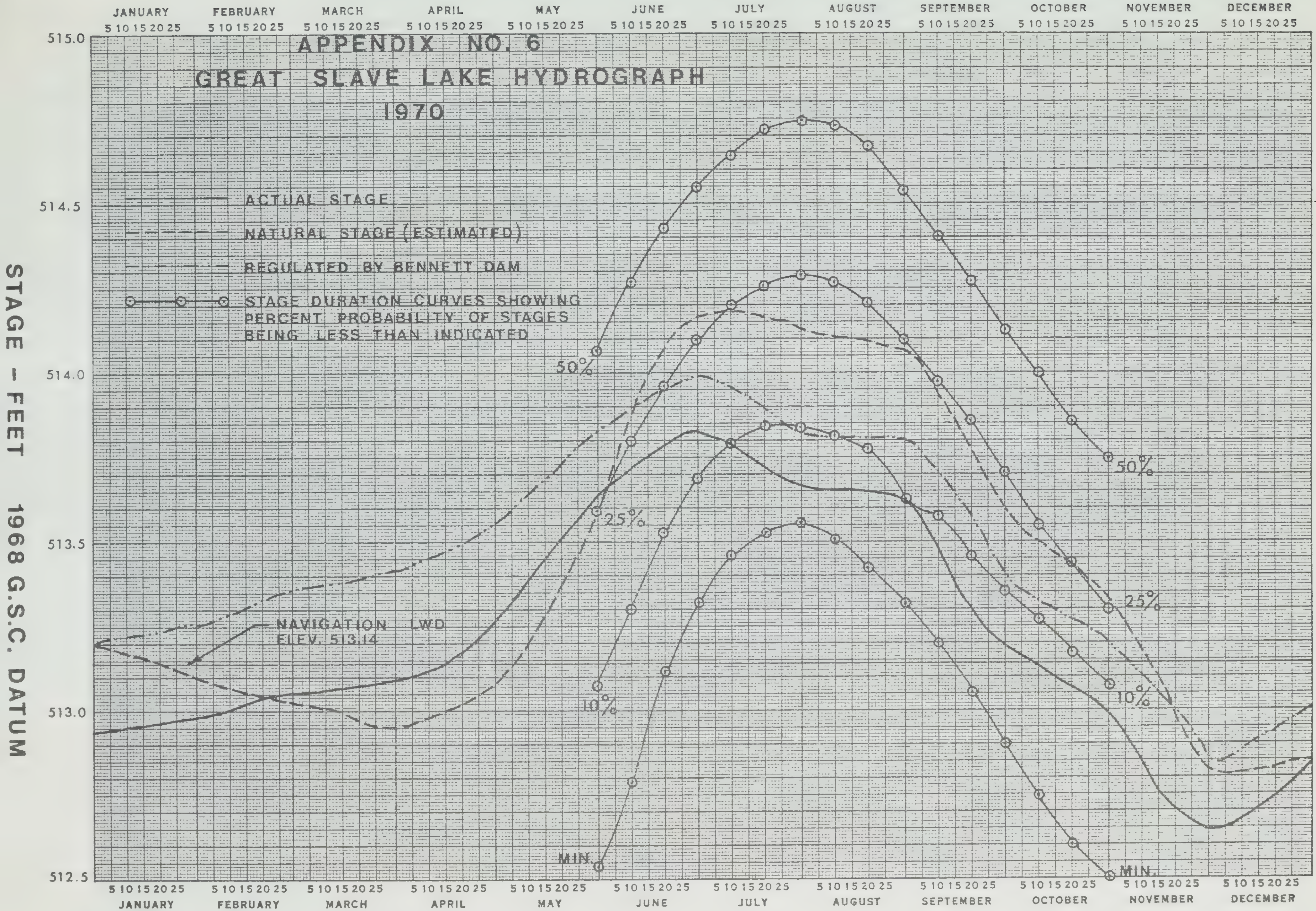


CHART Nº 5

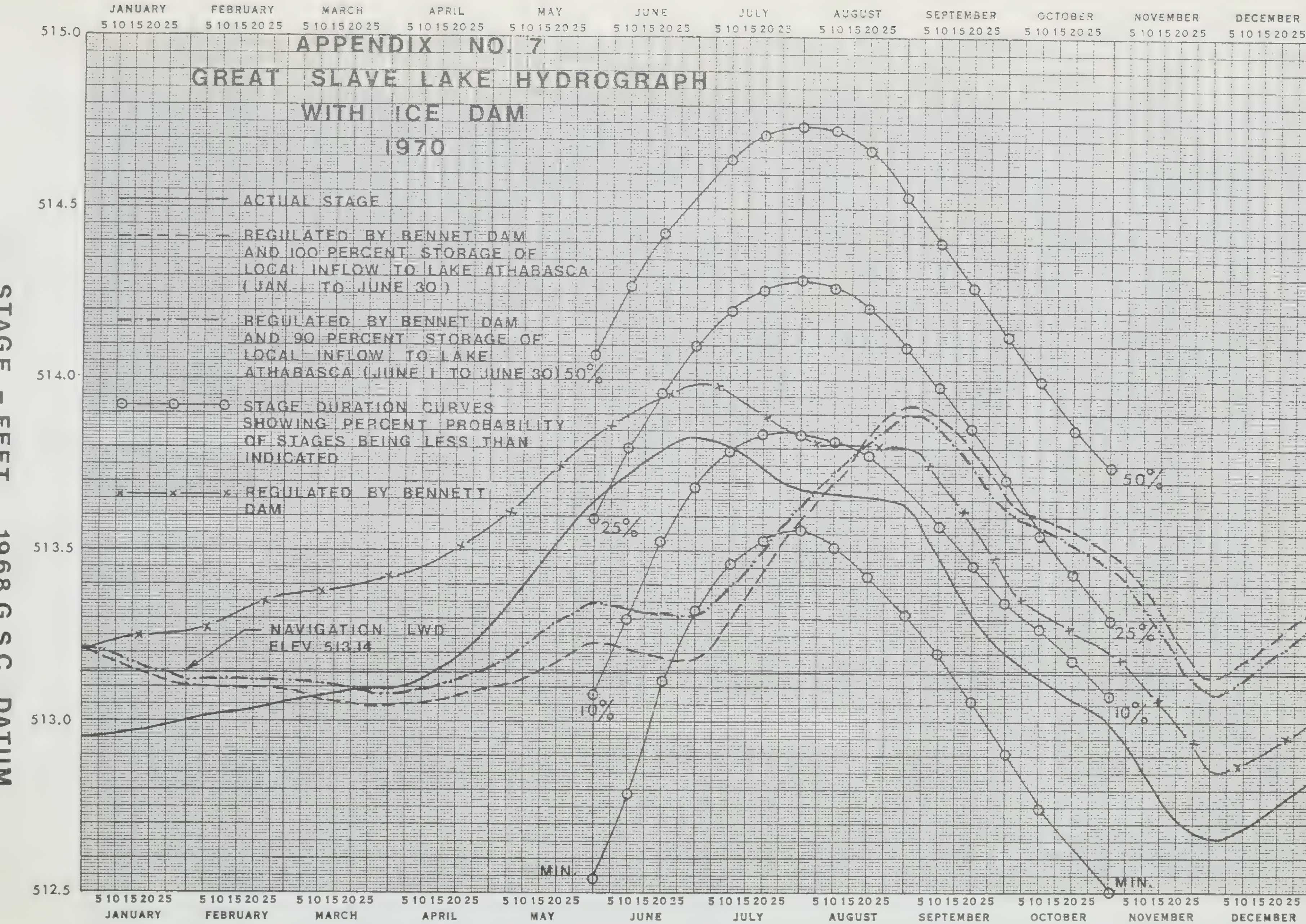
AVAILABLE COMMERCIAL BARGE ROUTES



Appendix 5 Annual Water-borne Freight Tonnages



GREAT SLAVE LAKE AT YELLOWKNIFE BAY 75B-1 1970



GREAT SLAVE LAKE AT YELLOWKNIFE BAY 75B-1 1970

SECTION N

SECTION N

RESEARCH COUNCIL OF ALBERTA

INTERIM REPORT

GEOLOGY OF THE PEACE-ATHABASCA RIVER DELTA REGION, ALBERTA

by

L. A. BAYROCK

and

J. D. ROOT

Geology Division

May 1972

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FOREWORD

This report is an interim report on the geology of the Peace-Athabasca Delta region, Alberta. It was prepared at the request of the Director of the Peace-Athabasca Delta Project, Mr. D. Hornby.

In the near future the Research Council of Alberta will publish a final report concerning the geology and geologic history of the area.

SUMMARY

The Peace-Athabasca Delta is underlain by Canadian Shield granites and gneisses, Athabasca Sandstone, and Devonian limestone and gypsum. The configuration of the bedrock surface underlying the Delta varies with the type of formation present. The bedrock surface of areas underlain by Canadian Shield rocks is knobby with local relief of 200 feet. The bedrock surface of areas underlain by other formations is nearly flat. Large preglacial valleys dissect the bedrock and these valleys have been overdeepended by glacial action. Towards the end of the recession of the continental icesheet large proglacial lakes covered the Delta region and thick deposits of inwash and glaciolacustrine sediments were laid down.

The Peace-Athabasca Delta began to form about 10,000 years ago and it now forms a composite, inland delta of the bird's-foot type. The Peace, Athabasca and Birch deltas occupy an area of 1475 square miles and, at present, extend their total area 1 square mile every 13 years. The Athabasca and Birch rivers are actively extending their delta areas but the Athabasca Delta accounts for the greater proportion by far. The Athabasca Delta has reached a point of development (the present distributaries are overextended) where migration of the active lobe is imminent.

The Peace Delta is now in an old stage of development because the Peace River bypasses the Delta. The delta receives sediment only during high flood stage of the Peace River so that area extension from sediment deposition is small. The Peace Delta is now effectively inactive and will remain so with the upstream regulation of water levels.

A series of barrier islands have formed (as a result of wave action in Lake Athabasca) which extend from Fort Chipewyan to Old Fort Point.

Most of the deposits on the surface of the delta are silts and clays deposited during flood stages. These silts and clays are suitable for road construction. Subsidence due to sediment compaction is evident on the margins of the Peace, Athabasca and Birch Deltas. Wave action has modified portions of the Delta which receive little sedimentation.

Two types of lakes exist in the Peace-Athabasca Delta: lakes connected to open water and lakes not connected. The connected or open lakes raise and lower their water level in response to water level fluctuations in the major lakes. The closed lakes enlarge or decrease in area in response to rainfall or floods.

Erosion features in the Mamawi Lake bed show that the Peace-Athabasca Delta has experienced very low later levels in the past.

No drastic changes will occur in the Peace Delta but the Athabasca Delta is a dynamic feature and large, abrupt changes in its configuration are expected in the very near future.

GEOLOGY OF THE PEACE - ATHABASCA DELTA

INTRODUCTION

Location and Size

The Peace-Athabasca Delta, one of the largest inland fresh water deltas of the world, is located in northeastern Alberta at the southwestern end of Lake Athabasca. It lies between 58°15' and 59°00' north latitude and 110°45' and 112°20' west of Greenwich. The total delta complex covers an area of 1475 square miles (3820 square kilometers) and is comprised of the following deltas: Athabasca Delta - 760 square miles (1968 square kilometers), Peace Delta - 650 square miles (1683 square kilometers) and Birch Delta - 65 square miles (168 square kilometers). Other very small deltas in the delta complex area are associated with the McIvor, Steepbank, Richardson and Maybelle Rivers, and Keane and Buckton Creeks. Though the Peace and Athabasca Deltas have merged they can be separated with reasonable confidence on the basis of the distributary patterns. The Birch Delta is separate from the main delta complex.

Access

Access to the Peace-Athabasca Delta is very difficult and is practically restricted to helicopter transport. Despite the flexibility of the helicopter the lack of suitable landing spots still limits surface mapping and sampling in the delta region.

Climate

The climate of the Peace-Athabasca Delta is warmer than the surrounding regions because of lower elevation and the moderating effects of Lake Athabasca and Lake Claire. The region's frost-free period, summer hours of bright summer sunshine, and mean annual snowfall are comparable to those of Edmonton, but the mean annual temperature is lower than at Edmonton. Lake evaporation is approximately equal to the mean annual precipitation (Longley, 1968). In general, summer temperatures at Fort Chipewyan are

comparable to those of Edmonton but for the rest of the year it is relatively colder.

Muskeg Accumulation

In warm climates, the accumulation of organic matter is minimal due to high fungal and bacterial action. In the far north, the accumulation of organic matter is very slow because cold climates inhibit plant growth. There is an intermediate climatic zone in which a maximum accumulation of organic matter occurs (maximum muskeg growth) because plant growth is significant and yet organic disintegration by bacteria and fungii is less than the yearly growth. The Peace-Athabasca Delta is situated in such a zone.

Permafrost

Discontinuous permafrost is present in the surrounding area (Lindsay and Odynsky, 1965), but due to the moderating effect of the large lakes it is not found in the delta.

Permafrost has been encountered at a depth of 89 feet on the extreme western shore of Lake Claire (Drill hole H-2, Appendix 1). During drilling, Dr. G. Nielsen reported that samples contained interstitial and clear ice at the 89 foot depth. No permafrost exists from the present delta surface to 89 feet and hence this ice and associated cold ground is considered to be fossil permaforst remaining from the last glacial age. Permafrost was also noted in drill holes G-2 at 3.5 feet and H-5 from 8 to 54 feet.

Fieldwork and Sources of Information

During the summer of 1970 the senior author mapped the distribution of surficial deposits in the Peace-Athabasca Delta as part of an overall survey of northeastern Alberta conducted by the Research Council of Alberta. The delta was traversed by helicopter and landings were made to sample and identify the surficial material.

In 1961 exploratory mapping of the soils was carried out by a team from the Research Council of Alberta which included the senior author (Lindsay *et al.*, 1962). During the Exploratory Soil Survey landings were

made in the delta area to identify and classify the soils. Original field notes and samples were made available to the authors for the present study.

Low-altitude, oblique aerial photographs of the delta taken in 1927 by the Royal Canadian Air Force were obtained for study from the Provincial Museum and Archives, Edmonton, Alberta. These photographs do not cover the entire delta area and only some of the significant portions are represented. Other aerial photographs taken in 1950 at a scale of 1:33,000 and in 1970 at a scale of 1:24,000 were also used in this study.

Samples of the subaqueous portion of the delta were supplied by Dr. A. A. Levinson, Department of Geology, University of Calgary, Alberta.

Lithologs of drill holes bored by Dr. G. Nielsen were supplied by the Water Resources Division of the Department of the Environment, Government of Alberta.

One water-well log was also consulted (on file at the Research Council of Alberta).

Previous Work

No previous systematic or detailed work on the geology of the delta is available. Early travellers through the delta noticed deltaic deposits and high water levels in the deltaic marshes. Alcock (1920) speculated on the origin of the Lake Athabasca basin and contended that the basin was produced by glacial erosion (overdeepening) of weak rocks that floored a pre-existing valley.

Acknowledgments

Acknowledgment is extended to the Research Council of Alberta for providing the information on which this report is based and the base map which accompanies the map atlas.

Dr. J. D. Godfrey (Research Council) provided the information on the Precambrian Shield rocks and read the manuscript critically.

Mr. F. Copeland compiled and drafted the base map and Mr. M. Baaske

performed the mechanical analyses of the samples provided by Dr. A. A. Levinson.

Dr. G. L. Nielsen, Water Resources Division, Department of the Environment, provided drill hole lithologs and mechanical analyses of drill hole samples, all of which were invaluable in the interpretation of the geology of the delta.

Thanks are especially due to Dr. G. B. Mellon (Head, Geology Division, Research Council of Alberta) who permitted the early expansion of the study and has given generously of his time and knowledge.

BEDROCK LITHOLOGY

General Setting

The Peace-Athabasca Delta is positioned at the edge of the exposed Canadian Precambrian Shield. Precambrian rocks are found east and north of the delta and Paleozoic gypsum and limestone are found to the west. Mesozoic rocks form the Birch Mountains southwest of the delta (Map 1). The delineation of bedrock types and bedrock topography beneath the delta is difficult. Only a small number of outcrops occur on the periphery of the delta region and the underlying bedrock and its topography have been inferred from these outcrops and the limited available borehole data.

Precambrian Igneous and Metamorphic Rocks

The Precambrian Shield complex of plutonic metamorphic-igneous rocks lies within the Churchill Province and therefore has been severely affected by the Hudsonian orogeny corresponding to an age of about 1800 million years before the present.

The migmatitic gneisses include biotite- and hornblende-bearing phases with small lenses of metasedimentary rock and amphibolite. The metasedimentary rocks are composed of impure quartzites, phyllites and schists, and locally may include minor amphibolite.

These gneisses have been intruded by massive to foliated granites that form bodies of varied sizes ranging from one hundred feet or less up to plutons over 10 miles in length.

The Precambrian terrain has a distinct northeasterly trend expressed by the steeply dipping metamorphic foliation of the rocks, the alignment of lenses and bands in the gneisses, the elongation of the granite plutons and the major faults of the area. Two zones of mylonitization (deep-seated wrench faults) also cross this rock complex parallel to the regional trend; a six-mile wide zone lies adjacent to the shore of Lake Athabasca, and a second two-mile wide zone passes through Flett Lake.

Athabasca Sandstone

Athabasca sandstone is not exposed in the delta area but it crops out

along the south shore of Lake Athabasca east of Old Fort Point. The sandstone is composed predominantly of fine- to medium-grained quartz with uncommon thin conglomeratic and shale stringers. Cementation of the formation is variable. In Alberta the sandstone is poorly cemented and friable and no really hard strata have been observed. The poor cementation observed in the outcrops may be the result of weathering and it is possible that the sandstone is much harder a short distance below the surface.

Athabasca sandstone occurs as subcrop on Bustard Island, and crops out on Burntwood Island and on the north shore of Lake Athabasca at Fidler-Point and just east of Fort Chipewyan.

Goose Island in the Athabasca Delta is not a deltaic island but is made of glacially-derived Athabasca sandstone rubble which forms a portion of the end moraine extending along Old Fort Point peninsula.

The thickness of the Athabasca Formation is variable. Though generally thinner at the margins, a boring towards the centre of the basin in Saskatchewan reveals a thickness in the order of 5000 feet. No thickness data are available for the formation in Alberta, but it should exceed 1000 feet in the major outcrop area south of Lake Athabasca.

Paleozoic and Mesozoic Formations

The surface of the Canadian Shield dips gently to the southwest, and no outcrops of Precambrian rocks occur west of a northwest-trending line running through Lake Mamawi and Lake Baril. West of this line Devonian strata overlie the Precambrian granites. A few limestone outcrops of the Slave Point Formation occur near the Birch River Delta. The Keg River and Muskeg Formations crop out on the Slave River but are not found in the Peace-Athabasca Delta area. These two formations are believed to underlie surficial deposits around the mouth of the Athabasca River and west of the Slave River close to the Peace-Athabasca Delta. Thus, they should form the bedrock of the Peace-Athabasca Delta west of Mamawi and Baril Lakes.

A map showing the gross distribution of bedrock formations and their lithology may be found in "Bedrock Geology of Northern Alberta," R. Green *et al.* (1969).

BEDROCK TOPOGRAPHY

Bedrock Topography Underlying Peace-Athabasca Delta

The Canadian Shield rocks which crop out in the Peace River Delta area are continuous in the subsurface with the rocks east of the Riviere des Rochers channel. By constructing projected profiles (of 4 miles projection width) it was determined that the local relief on the Shield is about 200 feet. A line on map 1 marks the theoretical position at which the highest knobs should crop out at the 700 foot elevation. The true westerly outcrop limit of the Precambrian Shield rocks in the delta area is shown to be some 10 miles east of the projected 700 foot line. Consequently, the topographic configuration of the basement beneath the delta west of the true outcrop line is uncertain. The discrepancy may be explained by either a greater downwarping of the Shield surface west of the outcrop line or vertical displacement along a fault. Aeromagnetic maps show evidence of two faults in that area (Map 1). In rocks of high aeromagnetic response (e.g. gneisses) faults are generally evident as valley lows on the maps. In summary, it may only be said that within the Precambrian outcrop area the local relief of the bedrock is about 200 feet. A line passing through Fort Chipewyan projected southwest from the northwest-trending shoreline of Lake Athabasca divides the Shield outcrops from the Athabasca sandstone outcrops within the study area. Aeromagnetic maps show a coincident contrast in response along this same boundary (Map 1). From these observations it is suggested that the bedrock surface under the Athabasca River Delta should be similar in configuration to that in Lake Athabasca.

Northeastwards from the delta the lake is shallow, from 10 to 25 feet deep, and it is assumed that the bedrock is probably not overlain by much recent sediment. Athabasca sandstone could be encountered some 20 to 30 feet below Lake Athabasca water level in that part of the Athabasca Delta.

Local relief on the Athabasca Formation south of Lake Athabasca is very subdued compared to the 200 foot local relief on the Precambrian Shield to the north.

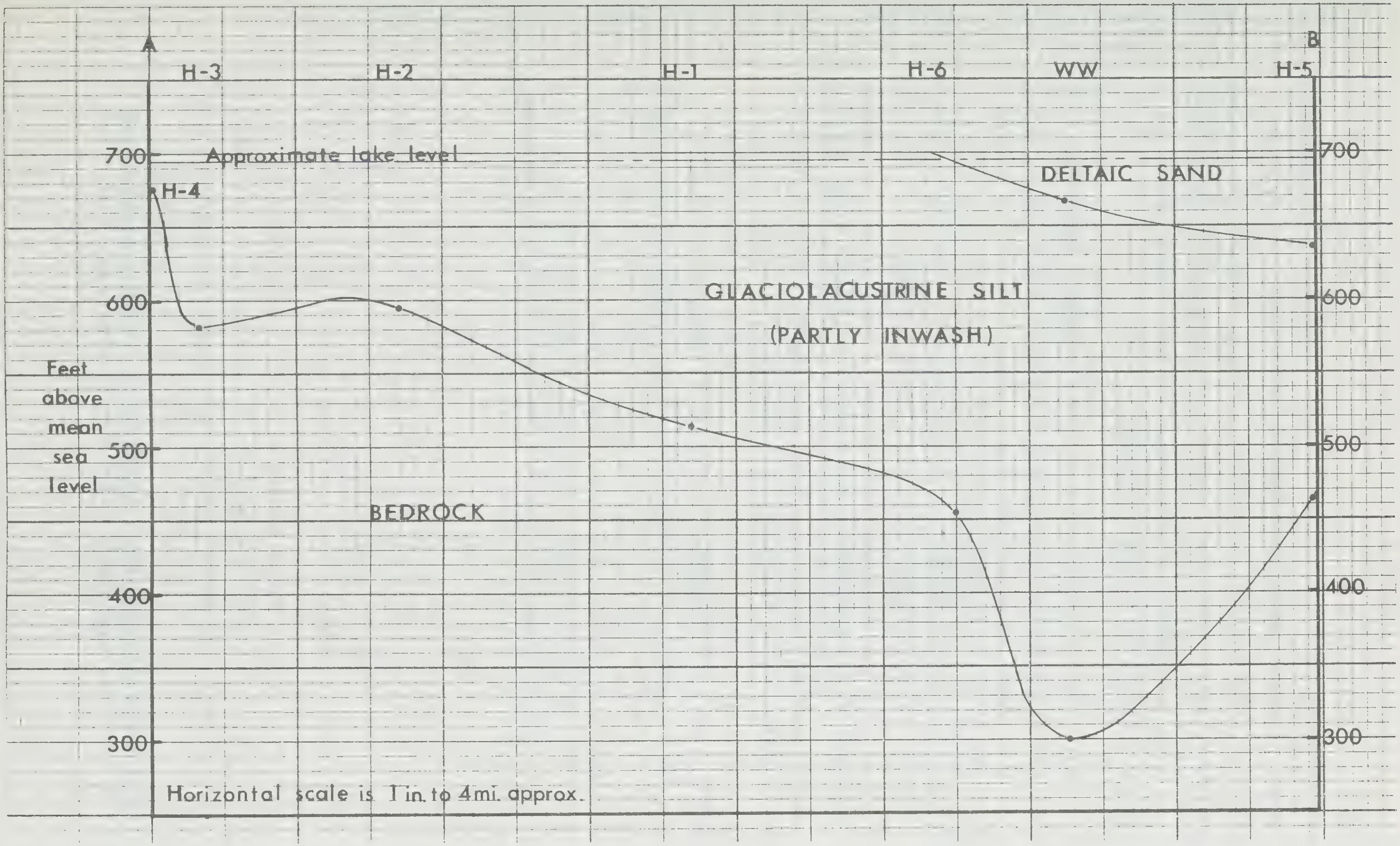
The bedrock surface of the Lake Claire portion of the basin can be interpreted on the basis of drill hole information supplied by Water Resources (Appendix 1). A vertical cross-section of the west shore of Lake Claire is shown in figure 1. The thalweg of the preglacial Peace River is positioned near the northern shore of Lake Claire and at that location bedrock is 400 feet below the surface. To the south near Spruce Point the preglacial bedrock surface is close to the present topographic surface. Hence, it is postulated that bedrock (Slave Point Formation) is relatively close to the surface under Lake Claire south of an east-west line through Spruce Point.

The Formation of Lake Athabasca Basin

Towards the end of the Cretaceous Period the extensive seas withdrew from northeast Alberta and from then on the area was subjected to continuous erosion. All the sediments overlying the Shield rocks in the Fort Chipewyan region were stripped off whereas west of the Slave River erosion removed strata down to Devonian formations. In the Birch Mountains area,erosion was less severe and Cretaceous strata are still present.

Towards the end of Tertiary time and at the beginning of the Quaternary Era the gross topographic features of the area were essentially the same as at present. In the very large broad valleys between the erosional remnants (the Birch and Caribou Mountains) large rivers flowed in positions similar to those at present. In the Peace-Athabasca Delta area three rivers converged. One came from the west along the course of the present Peace River, a second came from the south essentially along the course of the present Athabasca River, and the third came from the east through the basin of the present Lake Athabasca. All three rivers united and flowed northwards along the present Slave River route.

The Pleistocene Period began with the buildup of continental glaciers which repeatedly extended over large portions of North America. Pre-Wisconsin glaciers probably flowed in more or less the same direction as the Wisconsin continental glacier. Glacial striae show that the Wisconsin glacier flowed



Note: glacial till and outwash underlying glaciolacutrine silts are too thin to be shown.

Figure 1. Cross-section of bedrock surface from A-B, Map 1.

from the northeast parallel to the long axis of Lake Athabasca. The long axis of Lake Athabasca was also the thalweg of a preglacial river, and thus was a natural topographic low. Pleistocene continental glaciers followed the course of the preglacial river, accelerated the erosion and overdeepened the valley. Overdeepening could have resulted from the removal of soft rocks in the area of the present lake as postulated by Alcock (1920).

Lake Claire is positioned over the axis of the preglacial Peace River valley. Glaciers advancing from the northeast would follow the Peace River valley westward and overdeepening could have taken place in the Lake Claire area in the same manner as the Lake Athabasca basin. Hence, the deep portion of the preglacial Peace River valley (Fig. 1) may be the result of glacial overdeepening rather than being a feature of the original valley.

The deepest portion of the preglacial Peace River valley as shown on figure 1 is only 300 feet above sea level. Along the Slave River are many rapids and bedrock outcrops which preclude the presence of a large preglacial valley that their depth,[1] furthermore, there are no such valleys towards the eastern end of Lake Athabasca. In short is seems very likely that the deep portion of the Peace River valley has been produced primarily by glacial erosion.

The Athabasca River may also be positioned over an overdeepened preglacial valley near the Delta as outcrops are lacking along the Athabasca River close to the delta.

[1] L. A. Bayrock (1972): Surficial Geology, Peace Point-Fort Fitzgerald, Research Council of Alberta, map, scale 1:250,000 in press.

QUATERNARY HISTORY OF THE DELTA BASIN

Glacial History

The last glacier to cover the area advanced from the east-northeast as indicated by the large number of ice flow features present around the delta (Alcock, 1920), Glacial Map of Canada (Prest *et al.* 1967), and Godfrey (in preparation[2]). It is estimated that at the height of the last of Wisconsin glaciation the area was covered with up to two miles of ice.

The recession of the continental glacier from the area was marked by pauses and short readvances. During maximum glaciation the entire area was covered including the Birch and Caribou Mountains. As glacial recession proceeded the surface of the glacier was lowered and the Birch and Caribou uplands were exposed. Further lowering of the glacier surface exposed the uplands entirely and the margin of the glacier was positioned for a time in the lowlands west and south of the delta.

The glacier receeded further towards the northeast down the regional slope, and since the natural drainage of the area is also to the northeast glacial meltwater formed large lakes in front of the standing ice mass. These ice marginal lakes persisted until the final disappearance of the glacier from the area. Consequently, the deposits left in the lowlands surrounding the delta area are either glaciolacustrine or glacial outwash.

It is not possible to date the time of recession of the glacier from the delta as no samples have been radio-carbon dated. In Saskatchewan the Creek Lake moraine is tentatively dated as being about 10,900 $\pm$ 700 years old. This is based on a radio-carbon date of peat overlying till in front of the Cree Lake moraine (McCallum and Wittenberg, 1962, S - 123).

The Creek Lake moraine in Saskatchewan is one continuous moraine but in Alberta it splits into four separate moraines. These moraines are situated from the northern limit of the Muskeg Hills in the Bitumount map-area (74-L)

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[2] Godfrey, J. D: Geology of the Fort Chipewyan District, Northeast Alberta; Research Council of Alberta, Map, in preparation.

northwards to the south shores of Lake Athabasca. The small moraines in the delta area represent separate, short readvances of the glacier during the general recession. Ice-marginal lakes of different elevations are associated with each of these moraines.

Raised glacial lake beaches are well developed west of Lake Claire, west of the Slave River, and on both shores of Lake Athabasca up to 300 feet above the present water level of Lake Athabasca. The beaches on the west shore of Lake Claire show considerable tilting which indicates uneven postglacial isostatic readjustment.

Although individual raised beaches are continuous over long distances, correlation of beaches between different areas is not possible.

Proglacial lakes which occupied the area west and south of the delta received sedimentation directly from both the melting glacier and from the Athabasca and Peace Rivers. Material of nonglacial origin deposited in glacial lakes is called inwash. Both the Peace and Athabasca Rivers deposited thick proglacial deposits of this type in lakes around the delta area. Athabasca River inwash may be seen along the river valley for a distance of about 25 miles south of the Athabasca Delta. Inwash from the Peace River covers a much larger area; its extends from the lowland between the Birch and Caribou Mountains west of Lake Claire to about Vermilion Rapids on the Peace River, a distance of about 90 miles.

Postglacial History

As the proglacial lakes drained, the newly exposed and unvegetated inwash and outwash sediments were subjected to intense aeolian activity. This activity led to the formation of the presently stabilized sand dunes along the Athabasca River and in the lowlands west of Lake Claire. The major dune forming (storm) winds during this time were from the southeast. Dune forming winds at present are from the northwest. The inwash sediments can be readily distinguished from glacial sediments. The former contain coal and bituminous sand derived from the south and the west, whereas, glacial sediments in the Peace-Athabasca Delta area do not contain such organic materials.

Isostatic Readjustment

The recession of the continental glacier led to isostatic readjustment of the land. During the period of maximum development of the Wisconsin glacier, the glacier was about 10,000 feet thick over the delta. (The calculation is based on a formula derived by Nye [1959]). Ice cover of this thickness would depress the continent isostatically by about one third of the thickness of the glacier, then during and after the recession of the glacier the continent would rebound to its former elevation. The glacier was thickest towards the center of the former ice sheet and consequently the continent was depressed more there compared to the peripheral area. Corresponding postglacial isostatic readjustments of the continent are therefore greatest towards the former centers of continental glaciers compared to peripheral areas. The result of the differential movement is tilting of the continental surface during the rebound period.

Based on a series of abandoned beaches west of Lake Claire and on elevations along the 29th baseline (as recorded on the NTS sheet 84 I) it was calculated that the area is tilted up towards the northeast at the rate of two feet per mile. The tilt axis lies at about 40 degrees west of north. The rate of isostatic readjustment was probably highest at the start of deglaciation and it decreased exponentially with time. It can be assumed that the isostatic readjustment is now practically completed.

Surficial deposits of the area surrounding the Peace-Athabasca Delta have been mapped by the Research Council of Alberta on a scale of 1:250,000. Maps showing the distribution of the deposits are now in press and should be available by August 1972.

SEDIMENTATION

Inland Delta

The Lake Claire-Lake Athabasca basin is one continuous depression enlarged by glacial erosion and presently divided into two parts by the Peace-Athabasca Delta. The Peace-Athabasca Delta began to form approximately 10,000 years ago, immediately after glacial recession and draining of the proglacial lakes.

The Peace-Athabasca inland delta will eventually silt up the depression in which it is now growing and the rivers supplying the sediments will then flow through the delta without deposition. Geologically speaking an inland delta is a very short-lived feature of the landscape.

Separate Deltas

Although the Peace and Athabasca Deltas have merged, they can still be differentiated on the basis of their distributary configuration. Active or inactive individual distributaries may be traced back to the major river of their origin. The differentiation of the two major deltas is shown on map 5.

Deposition of Sediment Due to Loss of Current

Deltas are built by the deposition of sediments from streams as they enter bodies of water. A stream loses most of its turbulence on entering a body of water and the sediments are deposited. The river sediment is deposited in reasonably predictable patterns which make it possible to describe the past and future behavior of a delta.

Sedimentation Dynamics

An actively growing delta is a dynamic phenomenon. The position and size of the individual distributaries may change yearly but the greatest changes occur when the area of deposition shifts from one part of the delta to another. For example, since 1927 the distributaries of the Embarras River have been captured by the Fletcher Channel, and during recent geologic

time it can be shown that the Peace and Athabasca Deltas have changed their major distributary patterns on a large scale (Map 3).

Rates of Accretion

The Peace Delta has reached the stage of development at which deposition takes place only at flood times (old age). The Athabasca River deposits most of its sediments in the delta and is actively extending that area. The Athabasca Delta is 760 square miles in area and since it originated about 10,000 years ago it is being enlarged on the average at the rate of one square mile every 13 years. The Peace Delta is 650 square miles in area but it is not presently active and the period of inactivity is not known. The Peace Delta is in the old stage of development and the Peace River is bypassing it. Consequently, the growth rates for the Peace Delta have not been calculated. The Birch River Delta is 65 square miles in area and it enlarges its area by about one square mile every 150 years.

Sedimentation Patterns

The Peace-Athabasca Delta is a typical bird's-foot delta. The visible portion of the delta is the result of subaerial deposition in contrast to the portion of the delta which remains below the surface of the water (subaqueous deposition). The growth of the bird's-foot pattern is mainly the result of the buildup of levees along the distributaries to a height above the average water level during flood times. The distributaries commonly bifurcate and reunite to enclose depressions between them. These depressions become deltaic lakes and marshes.

During flood periods, water in the distributaries overflows the banks, sand is deposited on the levees, and silt and clay become trapped in the intervening lakes and marshes. Deltaic lakes in or near an active area of a delta may receive sedimentation during higher than normal water levels (but not necessarily during every flood) through a levee breach called a crevasse. A miniature delta usually forms at the mouth of a crevasse and extends into the lake. The crevasse may also serve as the drainage channel for the lake after a flood stage has receded. Thus, a lake may be flooded

and drained via the same crevasse leading into it. The crevasse is lower than the level of the top of the levee and once formed sedimentation of the deltaic lakes becomes accelerated. Crevasses are commonly resilted thereby resealing the deltaic lake.

Many of the deltaic lakes are directly connected to open major lake water. Such lakes are on the periphery of the delta in depressions between distributaries which have not yet united with other distributaries. In the Peace-Athabasca Delta region partly open deltaic lakes occur on the outer margins of the three deltas and in the zone between the Peace and Athabasca deltas. Mamawi Lake is an open lake between the two deltas.

Active Lobe Migration

A delta is similar in origin to an alluvial fan and in three dimensions they are both half-cone shaped. The gradient of the delta slope is less steep (the apex of the half-cone corresponds to the point where the river enters the delta area). As a delta grows it aggrades the level of the deposits at its terminus which also results in aggradation of the river bed upstream.

In all deltas, the part of the delta which is actively receiving sediment periodically migrates. The distributary channels overextend themselves and the main river abruptly abandons them in order to seek a shorter, steeper gradient to the water body. Over a period of time, the net result is a series of imbricated delta sediments which resemble many layers of overlapping sloping tiles. The sequence of the most recent active lobe migrations (geologically speaking) of the major detlas is shown on map 3. The distributary channels of the Athabasca River are, at present, well overextended to the east of the delta and migration of the active lobe of the Athabasca Delta is imminent. The most likely position for the new active lobe will be in Lake Claire of Mamawi Lake. The gradient from the Athabasca Delta apex to either Lake Claire or Mamawi Lake is much steeper than its present course.

Point Bar Deposits

Bedload is deposited on the inside of meanders. The deposits are called point bar deposits and are somewhat ridged. Most point bar depoists in the Peace-Athabasca Delta are made of sand and are found along both active and inactive distributaries throughout the delta region. Even some of the smallest distributaries in the delta have point bar deposits. A map of the distribution of point bar deposits of the delta has not been made because they could not be accurately delineated on 1:250,000 scale maps. (They could be delineated on 1:50,000 scale maps).

The point bar deposits of the Peace-Athabasca Delta range from course- to fine-grained sand but this deposit with silt and clay is frequently covered (from flood periods). Thus, older point bar deposits have a thicker silt cover than the more recent deposits. The depressions between individual point bars are gradually infilled with silt resulting in a smoother surface.

Rates of Sedimentation

The Peace-Athabasca Delta has been divided into three parts according to the present rates of deposition: active (continual sedimentation), semiactive (sedimentation annually) and inactive (little sedimentation except at extreme flood stage). The active parts of the delta are close to the water level of the lake. This part is devoid of vegetation and shows active depositional features such as extended levees, crevasses, crevasse deltas and enclosed lakes.

The semiactive parts are covered with sparse vegetation and are above lake water most of the time. The growth of vegetation in these areas is inhibited by considerable sedimentation (silt and very fine sand) during flood stages.

The inactive parts of the delta do not receive inorganic sediments at rates which inhibit plant growth and these areas are well above most lake water levels. Large portions of the inactive areas do not receive any sediment at present.

This classification and division is based on a detailed examination of air photographs supplemented by field data wherever possible. Map 5 shows the distribution of the three divisions.

Sedimentation in the Peace Delta

For much of the year the Peace River bypasses the Peace Delta and consequently most of the river's bedload is carried downstream to the Slave River and is not deposited in the Delta. During high flood stages considerable inflow from the Peace River into Lake Athabasca takes place through the Baril River, Chenal des Quatre Fourches, Riviere des Rochers and its fork Revillon Coupe. At the turn of the century the Claire River was also active. Very little bedload of the Peace River entered these channels during flood stages, and hence only silt and clay were deposited in Lake Athabasca. At low water stages (most of the year), the channels serve as outlets for Lake Athabasca water. The rate of sedimentation in the Peace Delta is periodic (high floods) and the areas are classified as semiactive. In the semiactive parts of the Peace Delta only silts and clays are present, in contrast, the semiactive areas of the Athabasca Delta is deposited during floods.

The upstream regulation of water levels of the effectively moderate high floods in the Peace Delta and hence eliminates sediment deposition in the Peace Delta. Some erosion may take place of the deltaic sediments in the semiactive portions. In the vicinity of Fort Chipewyan the absence of high floods on the Peace River may lead to deepening of the channels mentioned above.

Barrier Islands

An elongated bar extends from Fort Chipewyan to Old Fort Point across the mouths of the active distributaries of the Athabasca Delta. This bar is made primarily of sand which is highly compacted in places. In 1969, Professor A. A. Levinson (University of Calgary) sampled the sediments of the subaqueous portion of the Athabasca Delta. He found sampling to be a problem since the sand was so compact that the sampler would not penetrate. The origin of the

barrier island or bar is complex. The sand deposited over a wide area in front of the distributaries becomes subjected to intense wave action by the deeper waters of Lake Athabasca. The sand is rewashed, sorted and generally piled up into the bar shape.

Bars such as these are called barrier islands if the surface of the bar is occasionally above water level. The bar in Lake Athabasca is above water level at very low levels of Lake Athabasca and therefore it may be called a barrier island.

Surficial Deposits of the Delta

The surficial deposits in the delta region are sand, silt, and clay, with silt predominant. Appendix 1 gives mechanical analyses of drill-hole samples of the deep holes on the west shore of Lake Claire and some of the hand auger samples of shallow holes in the delta. Locations of the drill holes are shown on map 2.

Samples from hand-auger holes E-1, E-2, E-3, F-1, F-2, and D-3 are of similar composition, made up of silt (60 to 70 percent) and clay (20 to 40 percent) with smaller amounts of sand (less than 10 percent). (These holes were bored across distributary levees (i.e. 90 degrees to the direction of flow) and the numbers following the letter designate the position in the drilling profile. Number 1 is close to the distributary channel and higher numbers extend successively towards the lake adjacent to the levee).

Drilling logs of the auger borings are given in appendix 2. Some of the logs give the composition of the materials as silt, and others show more variation in the deposits. They all show that the predominant material is silt with clay. Sand constitutes only a small portion of the deposits.

A helicopter survey performed by the senior author shows that silt and clay covers most of the inactive part of the delta (inactive part designated on map 5). The active and semiactive parts of the delta and levees along the Athabasca River and other major channels of the delta contain considerable amounts of fine-grained sand. Similar results were obtained by Lindsay *et al.* (1962).

The occurrence of silt and clay at the surface throughout the delta region is due to periodic inundation by sediment-laden flood waters.

There are two causes of floods in the Athabasca Delta. The first is floods resulting from ice-jams which occur during break-up in the spring. Very large ice-jams form on the Athabasca and Embarras Rivers near Richardson Lake and these rivers overflow their banks and flood the surrounding delta.

The second type of flood occurs in July and results from high precipitation and high runoff. It also causes bank overflow and inundates many of the deltaic lakes.

The ice-jam flood in the spring of 1971 was observed by the senior author. During this flood, flood waters from the Athabasca River containing suspended silt and clay inundated most of the delta south of the Athabasca River and large areas along Mamawi Creek and the terrain between the Embarras River and Lake Claire. During the July flood of the same year much of the terrain was inundated. The authors have examined an aerial photograph mosaic taken during that flood and the results of the flooding appear similar to the results of ice-jam flooding.

At both times most of the deltaic lakes of the Athabasca Delta were flooded with water carrying a suspended load. These floods and similar periodic floods during the past (most commonly annually) account for the surficial deposits of silt and clay found throughout the inactive parts of the Peace-Athabasca Delta. In the active and semiactive parts of the Delta very fine- to medium-grained sands are deposited.

Wave Action

Deposits of fine- to medium-grained sand are found along extensive beaches throughout the inactive part of the delta. These beaches have been mapped from aerial photographs and are shown on map 4. They have a northeast-southwest orientation that reflects the direction of the prevailing storm winds (and hence the beach forming winds) from the northwest.

A comparison of 1927, 1950 and 1970 aerial photographs reveal that wave erosion has breached levees in two locations during that period. It may be postulated that wave action is responsible for much of the truncation and destruction of levees in the inactive and subsided areas.

Atterberg Limits of Deltaic Sediments

Liquid and plastic limits were determined on four samples collected in 1969. Three of the samples were from dry delta flats (i.e. former deltaic lake beds) and one is from the levee of the Athabasca River. Sample locations are shown on map 2. The levee sample is made of very fine-grained sand and has a very low liquid limit and plastic index (sample LB-69-93-2). The other three samples (LB-69-93-3, LB-69-95-1, and LB-69-95-2) are of medium plasticity (Fig. 2) and under normal conditions soils having these physical properties are suitable for the construction of highways and other structures designed to support loads.

The Delta's surficial deposits are very similar in composition. From this data it follows that if the three samples are representative of the soils found in the Delta, there should be little problem in constructing all-weather roads through the area. It should be pointed out that this conclusion is based on the analyses of only three samples. However, a more thorough survey should substantiate this conclusion.

Subsidence

Silts and clays are deposited in an oozy state in aqueous environments and thereafter undergo considerable compaction after expulsion of the interstitial water. Silts and clays may compact as much as 90 percent of the depositional volume. Most of the compaction takes place very shortly after deposition, but compaction continues for a much longer time. Many deltas around the world show compaction and the resultant subsidence.

Subsidence in the Peace-Athabasca Delta is characterized by the following: levees below lake water levels, truncated levees close to lake water level and partially destroyed by wave action, and levees in the process of being destroyed or breached by wave action.

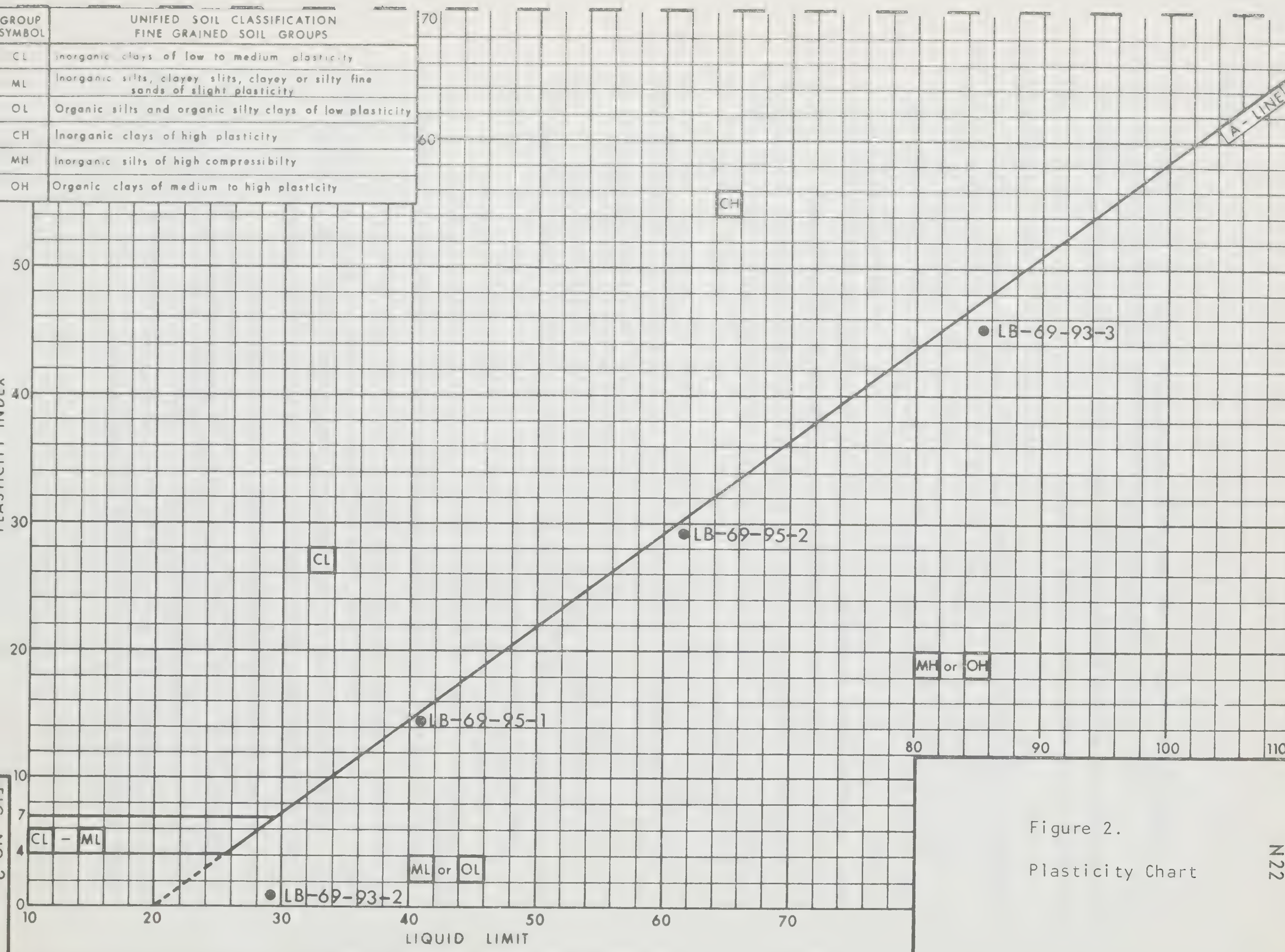

Figure 2.

Plasticity Chart

Map 6 was constructed showing terrain that has undergone subsidence according to the above criteria.

Subsidence areas are more extensive in the Peace Delta than in the Athabasca Delta. This is to be expected because the Peace Delta is made up of a greater proportion of silt and clay than the Athbasca Delta. The Birch Delta also shows significant subsidence. No subsidence was visible in the active or semiactive portions of the Athabasca Delta, but there are some indications of subsidence in the semiactive portion of the Peace Delta.

Deltaic Perched Water Table Lakes

During high floods all deltaic lakes receive silt- and clay-laden waters from the Peace and Athabasca Rivers. These flood waters carry only the suspended load of the rivers to the lakes as the coarse material settles out on the levees.

Flood waters usually remain in these lakes for sufficient time to allow silt and clay to settle out and this clay provides a uniform, impermeable lining to the bed of many of the deltaic lakes. Most of the clay minerals present in the sediments contain a high proportion of montmorillonite derived from bentonitic Cretaceous Formations.

The evaporation from lake surfaces in the Delta area approximately equals the annual precipitation. Hence, lake levels should remain constant where no direct drainage is involved.

Some deltaic lake levels are maintained with flood water and because precipitation is equal to evaporation the levels tend to remain at their high level for a long time. Lakes with drainage channels or open lakes connected directly to the main lakes will adjust their water levels in response to the water level at the outlet or to the main lake level. Closed lakes will not necessarily respond to changes in levels of the major lakes.

Closed lakes in the delta area which have a significant clay lining, (and most of them do) maintain or change their levels regardless of the levels of the major lakes. A heavy rainfall will raise the levels of these

lakes very quickly and the high levels will persist for a long time. These lakes are called perched water table lakes.

Subaqueous Sedimentation

The subaqueous portions of the Athabasca and Birch Deltas have been sampled by Dr. A. A. Levinson and aliquots of the samples were supplied to the authors. The results of sieve analyses on the samples (wet sieving through a 250 mesh screen) are shown on tables 1 and 2, appendix 4. Sample locations are shown on map 2. Samples from the subaqueous portion of the Birch Delta are numbered 1 to 19 and the remainder from Lake Athabasca are numbered 23 to 50. Figure 3 shows the sand percentage at the sample locations in Lake Claire, and figure 4 shows sample location in Lake Athabasca.

In Lake Athabasca the distribution of samples that are predominantly sand correspond to the position of the barrier islands described previously. Samples north and northeast of the barrier islands are almost exclusively silt and clay.

Sediments of the subaqueous portion of the Birch Delta are composed predominantly of silt and clay. Two samples (7 and 19) each contain about 40 percent of sand.

Subaqueous Birch Delta sediments are predominantly silt and montmorillonitic clay derived from Cretaceous Formations in the Birch Mountains.

The sand fraction of the Birch Delta sample was examined under the microscope and was found to be composed predominantly of iron oxide oolites derived from the Cretaceous Formations.

Relative Ages of Delta Segments

Deltas change the locations of their active distributaries from time to time and thus different segments of the delta receive renewed sedimentation. The Peace and Athabasca Deltas are subdivided into four age categories and the Birch Delta into two by using the amount of peat formation, the degree of destruction of the delta, subsidence of the delta, and the unaltered, new appearance of distributaries (Map 3).

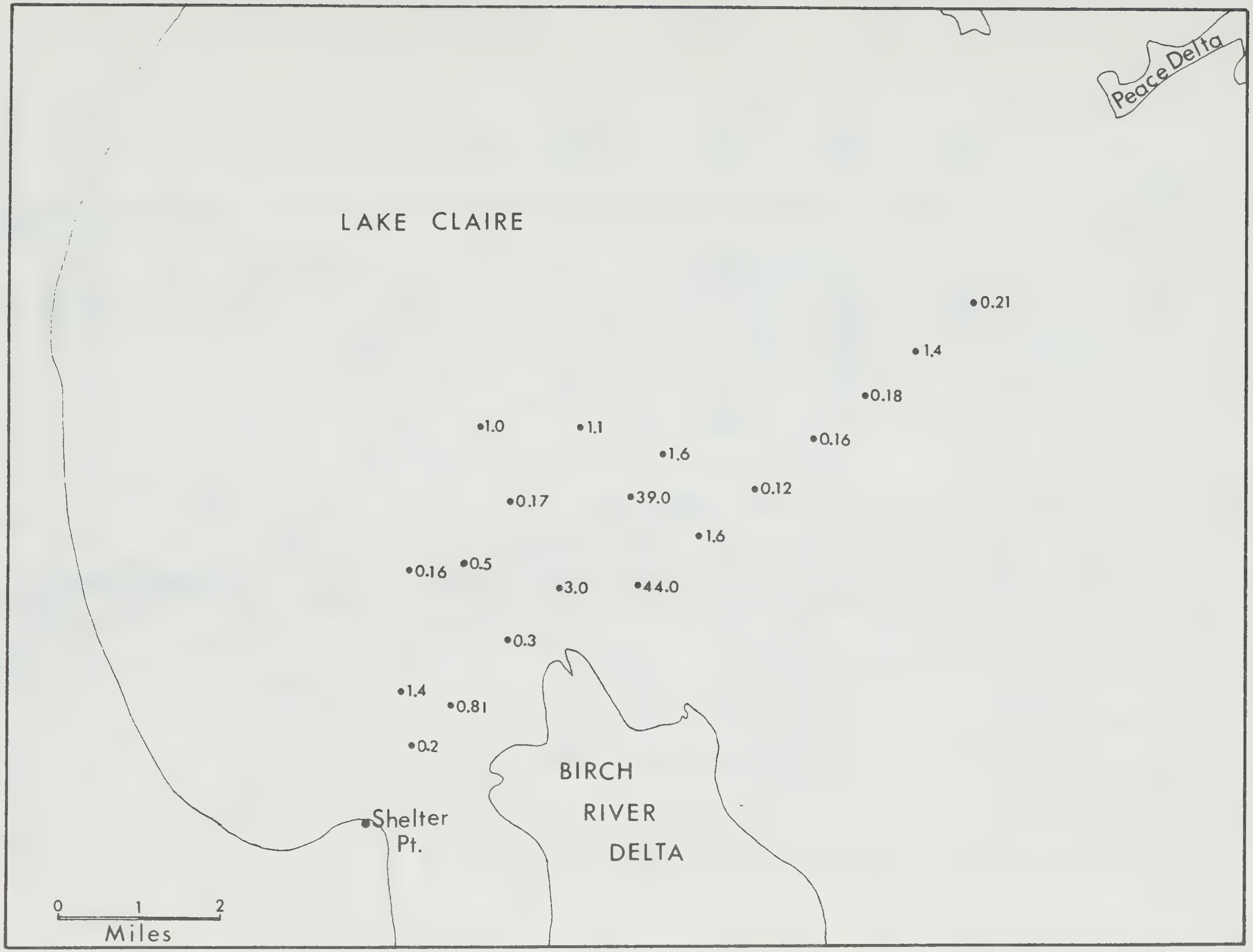

Figure 3. Sand percentage of subaqueous samples in Lake Claire.

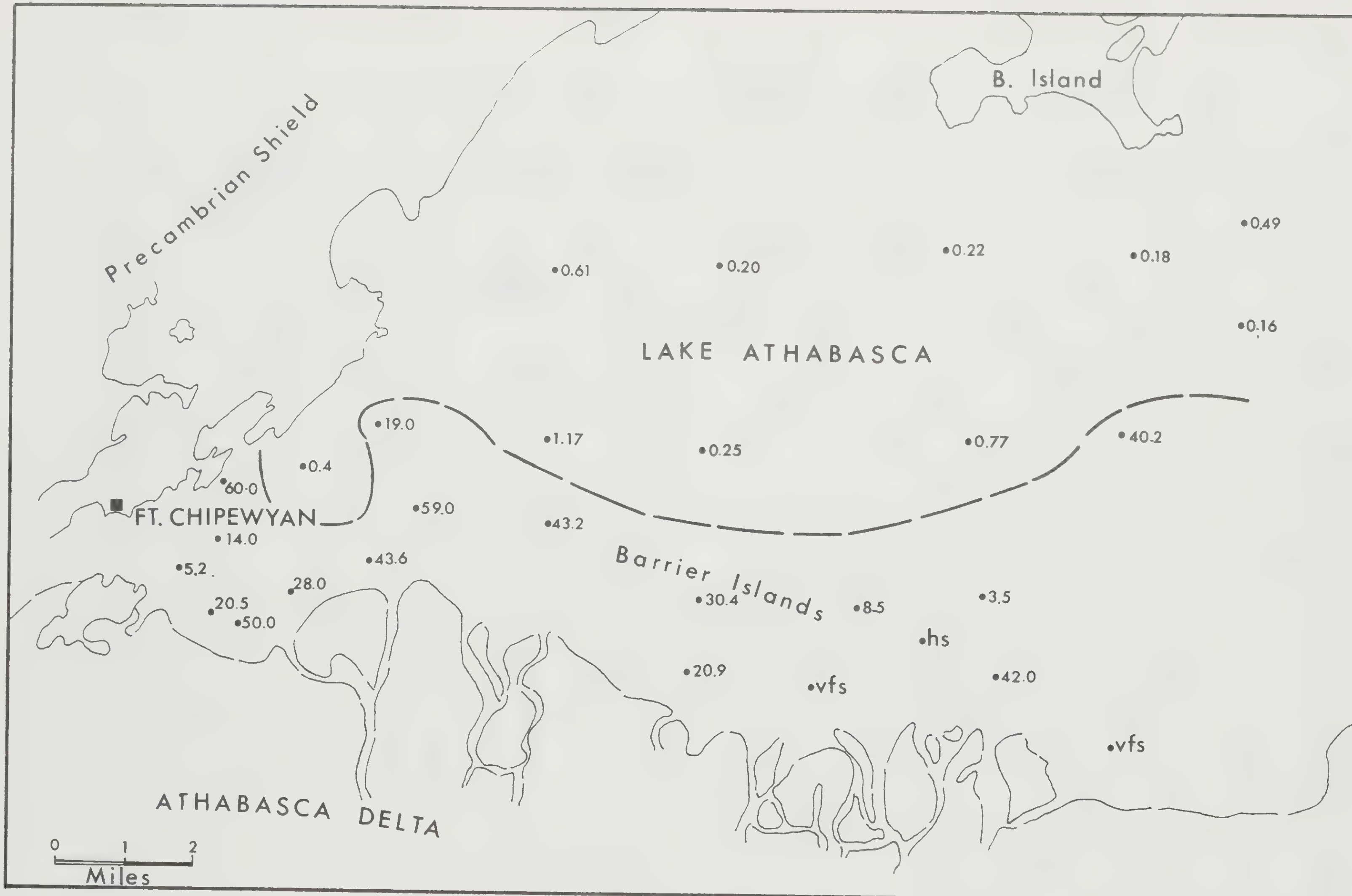

Figure 4. Sand percentage of subaqueous samples in Lake Athabasca.

The relatively older delta segments are not correlated between the individual deltas (i.e. area 3 in the Peace Delta and area 3 in the Athabasca Delta are not necessarily the same are).

The oldest segment of the Athabasca Delta is estimated to be about 3000 years in age (determined on the basis of peat three feet in thickness, which is known to accumulate there at a rate of one foot every 1000 years). No attempt was made to date the surface of the lobes of the Peace and Birch River deltas.

Changes in the Size of Lakes

Aerial photographs taken in 1950 were compared with photographs taken in 1970. It was noted that the dimensions of many deltaic lakes changed, some became larger while others became smaller. A map has been constructed showing the dimensions of lakes in 1970 compared to 1950 (Map 7).

At the time of the 1950 photography (September 10, 1950) the level of Lake Athabasca was 684.2 feet above sea level. During the 1970 photography (October 15, 1970) the Lake Athabasca level was 682.0 feet.

Map 7 shows that open deltaic lakes and most lakes connected by channels or crevasses to flowing or open water decreased in area whereas most of the closed lakes increased in area. The closed lakes are perched water table lakes (as described above) and these lakes are not connected to flowing or open water. It is postulated that the heavy rainfall just prior to the 1970 photography filled these lakes and consequently the occupied larger areas. Lakes which decreased in area are connected to open water of the major lakes and consequently adjusted their level to correspond with the water level of Lake Athabasca.

Low Water Levels of Mamawi Lake

Aerial photographs taken in 1970 show partly buried drainage channels and dendritic erosion patterns in the deepest portions of Mamawi Lake. Mamawi Lake is so shallow that on these photographs its bed may be observed

through the lake water. The formation of dendritic drainage patterns on the bed of Mamawi Lake requires that the lake bed be dry at some time in the past. It is not known when such low water levels existed, but a rough estimate would be sometime during the last 200 years. As Mamawi Lake is directly connected to Lake Athabasca, the low water stage must also correspond to a similar low water stage in Lake Athabasca. Such a low water stage (or stages) is lower by about 4 feet than the October 15, 1970 level of 682.0 feet.

Athabasca River Meander Near Embarras Portage

The outside of a large meander on the Athabasca River near Embarras Portage is actively eroding its west bank and in the near future the river will cut through at this point and flow into the adjacent Embarras River. Further details on this situation are included in two reports in appendix 5.

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APPENDIX 1

DRILL HOLE LOGS

The holes were drilled by Dr. Grant Nielsen, Water Resources, Alberta Government, in the spring of 1972. The following are drilling logs based on field description. Genetic interpretation of surficial geological materials is by the authors of this report.

Hole No. H-1

Date: March 12, 1972

Depth (ft)	
	Glaciolacustrine
0-40	silt, light brown, calcareous, soft
40-88	silt, light grey, calcareous, soft
88-145	sandy silt, light grey, calcareous, soft
	Glacial
145-156	till, light grey, gypsum and granite pebbles
	Glacial outwash
156-170	sand, poorly sorted, calcareous
	Bedrock
170-	end of hole - too hard to drill, bedrock?

Hole No. H-2

Date: March 13, 1972

Depth (ft)	
	Glaciolacustrine
0-6	peat, black, soft
6-32	silt, light grey, calcareous, hard
32-40	silt, light grey, very soft
40-48	sand, very fine, slightly silty, calcareous
48-80	silt, light grey, very soft, calcareous
80-88	silt, clayey, light grey, calcareous, very soft
	Glacial outwash
88-89	sand and gravel, pink clay, quartz pebbles, gypsum, glacial permafrost at 89 feet - temperature of samples - 5°C.

Hole No. H-3

Date: March 14, 1972

Depth (ft)	
	Glaciolacustrine
0-16	silt, sandy, grey, calcareous, soft
16-105	silt, light grey, calcareous, soft
	Glacial
105-112	till, reddish, very sandy, gypsum pebbles
	Bedrock
112-	end of hole, bedrock, gypsum, bedded, white to pink

Hole No. H-4

Date: March 14, 1972

Depth (ft)	
	Glacial
0-8	till, gypsum, limestone and granite pebbles and cobbles
	Bedrock
8-11	bedrock, gypsum, white, soft, bedded
11-	end of hole

Hole No. H-5

Date: March 15, 1972

Depth (ft)	
	Alluvial and deltaic - Peace River
0-7	sand, some wood fragments
7-8	silty sand, wood fragments
8-72	sand, angular to subangular, calcareous, occasional organic layers
	Glaciolacustrine
72-240	silt, light grey, calcareous, soft
240-243	sand and fine gravel, granite and quartz pebbles

Hole No. H-6

Date: March 16, 1972

Depth (ft)	
	Organic - Recent
0-4	peat, black, soft
	Glaciolacustrine
4-227	silt, grey, sticky, calcareous
	Bedrock
227-232	bedrock, claystone, brick red, gypsum
232-	end of hole

Hole No. WW

Depth (ft)	
	Deltaic - Peace River
0-25	sand
	Glaciolacustrine
25-391	soft, silt
	Outwash, till?
391-392	gravel with granite boulders
	Bedrock
392-400	bedrock, red shale, soft
400-	end of hole

APPENDIX 2

HAND AUGER DRILL HOLE LOGS

A-1[1]	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
A-2	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
A-3	Location:	NE-21-9-111-W4
	Lithology:	0-10 feet - silts
B-1	Location:	Lsd 6-29-9-111-W4
	Lithology:	0-10 feet - silts
B-2	Location:	Lsd 8-29-9-111-W4
	Lithology:	0-10 feet - silts
B-3	Location:	Lsd 8-29-9-111-W4
	Lithology:	0-10 feet - silts
C-1	Location:	Lsd 11-27-9-111-W4
	Lithology:	0-10 feet - silts
C-2	Location:	Lsd 12-27-9-111-W4
	Lithology:	0-10 feet - silts
D-1	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-4 feet - sandy silt, organic material
		4-8 feet - sand, very fine, calcareous
		8-10 feet - sandy silt
D-2	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-2 feet - silt, organic material
		2-6 feet - sandy silt
		6-8 feet - silty sand, very fine
		8-10 feet - sandy silt
D-3	Location:	Lsd 9-6-6-109-W4
	Lithology:	0-2 feet - sandy silt
		2-6 feet - sand
		6-8 feet - silt
		8-10 feet - sandy silt
E-1	Location:	Lsd 8-6-6-109-W4
	Lithology:	0-4 feet - sandy silt
		4-6 feet - silty sand
		6-10 feet - sandy silt
E-2	Location:	Lsd 12-5-6-109-W4
	Lithology:	0-6 feet - sandy silt
		6-8 feet - silty sand
		8-10 feet - sandy silt

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[1] Drill hole number

E-3	Location:	Lsd 5-5-6-109-W4
	Lithology:	0-6 feet - sandy silt
		6-8 feet - silty sand
		8-10 feet - sandy silt
F-1	Location:	Lsd 7-36-109-6-W4
	Lithology:	0-8 feet - sandy silt
		8-10 feet - silt
F-2	Location:	Lsd 8-36-109-6-W4
	Lithology:	0-4 feet - silty sand
		4-8 feet - sandy silt
		8-10 feet - sand
G-2	Location:	NE-21-12-114-W4
	Lithology:	0-1 feet - organic silt
		1-4 feet - silt
G-3	Location:	SW-16-12-114-W4
	Lithology:	0-1 feet - clay, organic material
		1-2 feet - silt, organic material
G-4	Location:	NW-5-12-114-W4
	Lithology:	0-0.8 feet - silty clay
		0.8-1.3 feet - sand, very fine
		1.3-2.0 feet - silty sand
		2-4.5 feet - sand, very fine
		4.5-9.0 feet - sand, fine
G-5	Location:	NW-29-12-113-W4
	Lithology:	0-0.3 feet - loam
		0.3-0.5 feet - clay
		0.5-1.0 feet - silt
		1-9.0 feet - sand, very fine
		9-10 feet - silt, sticky

APPENDIX 3

MECHANICAL ANALYSES

Mechanical analyses of drill hole samples collected by Dr. Grant Nielsen, Water Resources, Alberta Government.

Sand-silt-clay percentages of drill hole samples

Drill Hole No.	Depth (ft.)	Sand	Silt	Clay	Drill Hole No.	Depth (ft.)	Sand	Silt	Clay
D-3	10	10	73	17	F-2	2	6	65	29
E-1	2	20	68	12	F-2	4	0	57	43
E-1	4	13	70	17	F-2	6	4	54	42
E-1	6	8	71	21	F-2	8	9	63	28
E-1	8	7	71	22	F-2	10	41	35	24
E-1	10	5	69	26	H-6	24	6	45	49
E-2	2	5	77	18	H-6	40	8	62	30
E-2	4	19	66	15	H-6	64	3	49	48
E-2	6	7	73	20	H-6	80	2	73	25
E-2	8	3	74	23	H-6	104	2	58	40
E-2	10	5	71	24	H-6	120	4	65	31
E-3	2	3	74	23	H-6	136	0	45	55
E-3	4	3	66	31	H-6	168	0	45	55
E-3	6	3	63	34	H-6	184	0	24	76
E-3	8	5	75	20	H-6	192	0	4	96
E-3	10	3	74	23	H-6	216	5	34	61
F-1	2	10	73	17					
F-1	4	8	71	21					
F-1	6	8	68	24					
F-1	8	4	69	27					
F-1	10	6	72	22					

APPENDIX 4

ANALYSES OF SUBAQUEOUS SAMPLES

Table 1. Analyses of subaqueous samples[1] - Lake Claire

Sample	Sand[2]	Silt & Clay[2]	Sample	Sand	Silt & Clay
1	0.21	99.79	11	0.20	99.80
2	1.40	98.60	12	1.40	98.60
3	0.18	99.82	13	0.16	99.84
4	0.16	99.84	14	0.50	99.50
5	0.12	99.88	15	0.17	99.83
6	1.60	98.40	16	1.00	99.00
7	44.00	56.00	17	1.10	98.90
8	3.00	97.00	18	1.60	98.40
9	0.30	99.70	19	39.00	61.00
10	0.81	99.19			

[1] Samples collected by A. A. Levinson, Department of Geology, University of Calgary

[2] Sand, silt and clay in percentages

Table 2. Analyses of Subaqueous Samples[1] - Lake Athabasca

Sample	Sand[2]	Silt & Clay[2]	Sample	Sand	Silt & Clay
23	42.00	58.00	39	8.50	91.50
24	5.20	94.80	40	30.40	69.60
25	20.50	79.50	41	0.25	99.75
26	50.00	50.00	42	0.20	99.80
27	28.00	72.00	43	0.61	99.39
28	43.60	56.40	44	1.17	98.83
29	20.90	79.10	45	43.20	52.80
32	40.20	59.80	46	59.00	41.00
33	0.16	99.84	47	19.00	81.00
34	0.49	99.51	48	0.40	99.60
35	0.18	99.82	49	60.30	39.70
36	0.22	99.78	50	14.00	86.00
37	0.77	99.23	30	very fine sand[3]	
38	3.50	96.50	31	very fine sand[3]	

[1] Samples collected by A. A. Levinson, Dept. of Geology, University of Calgary.

[2] Sand, silt and clay in percentages

[3] Field description only

APPENDIX 5

Reports by T. Blench and L. A. Bayrock on the condition of the meander on the Athabasca River near Embarass Portage.

N39

14203 - 54 Avenue,
Edmonton, Alberta

May 7th, 1972

Mr. D. M. Hornby, Director,
Peace - Athabasca Delta Project,
512 Baker Centre,
10025 - 106 Street,
Edmonton, Alberta.

Dear Mr. Hornby:

Geologic Conditions of the Athabasca River Bend near Embarras Portage.

1 The following are my additions to and discussions of the report submitted to you by Dr. T. Blench and Associates Ltd. dated April 28th, 1972, in which hydrologic and engineering conditions of the bend of the Athabasca River near Embarras Portage.The bend constitutes a meander of the Athabasca River in the upper portions of the Athabasca Delta. The meander was visited on April 13th, 1972, by helicopted with Messrs. Blench, Yaremko, Card, and Root, while the Athabasca River was still frozen.

2 The previous spring, April 27th and 28th, 1971, the meander was inspected only from the air as it was in a high flood stage caused by ice jams downstream from the location. A description of the conditions in the spring of 1971 is given in the report on geologic situations at the proposed dam site locations in the Athabasca - Peace delta. The report was submitted to R. M. Hardy and Associates Ltd., Edmonton, and a copy of it has been forewarded to you on May 6th, 1972. A Xerox copy of the pertinent pages of the report are enclosed. The possible changes resulting from a breakthrough of the Athabasca River into the Embarras River were discussed in the report and these are essentially the same as held by me at present.

3 On April the 13th of this year the width of the land between the Athabasca and the Embarras rivers was measured - it was found to be 174 feet. The measured traverse is markes with seismic tape on trees. Upon closer examination it was realized that the measured traverse is perhaps ten feet longer than the shortest distance by about ten feet. In other words the shortest distance between the two rivers may be close to 165 feet.

4 On the basis of aerial photographs taken from 1927 to the present it has been estimated that the average yearly erosion rate of the bank between the two rivers is about 3 feet. But it should be noted that the

rate of erosion has been on the increase the last few years, and may be close to 45 feet per year at present.

5 The bank is mainly made of very fine sand and some silt which is very susceptible to erosion. The height of the bank as measured above the ice of the Athabasca River was about 14 feet and on the Embarras side it was the same.

6 I agree with Dr. Blench that the Athabasca River may bypass the meander and cut through the meander loop shortening its course and bypassing the bend.

7. On the other hand if the Athabasca River continues its cutting of the bank towards the Embarras River it may in a relatively short time, within one to three years empty itself into that river.

8. Depending on flood conditions of the Athabasca River the break-through may occur anywhere from one to three years. There were two floods at this location in 1971. The first was the ice jam flood in early May, and the second the normal runoff flood in July. At both times the Athabasca river overran its banks and also produced considerable erosion which unfortunately was not measured. The July flood most likely caused the major amount of erosion of the banks as during the first flood the ground was frozen.

9. If the break through to the Embarras should occur first, and it is my opinion that this is most likely to happen, the whole or most of the Athabasca River will be diverted into it in a very short time, maybe within days.

10. The banks of the Embarras River are only about four feet high at points south of the Mamawi Creek, as observed from the air but not measured on the ground. At this location there also occur a number of incipient small channels caused by the overbank flow of the Embarras River towards the Mamawi Creek. Some of these channels originate on the banks of the Embarras River.

11. The Embarras River is at present much smaller than the Athabasca River and also occupies a narrower valley. In case of a break through the high water level may in a short time result in an avulsion towards Lake Mamawi via the Mamawi Creek.

12. Lake Mamawi is very shallow and in a few years it would become completely silted up. The Athabasca River than would most likely flow directly to the Slave River through one of the many existing channels connecting the Peace River with Lake Athabasca.

13. After the break through of the Athabasca into the Embarras, the combined waters in the Embarras may overflow the banks in the Mamawi Creek area and flow directly into Lake Claire. In this case the Lake would be silted up and the Athabasca would again follow one of the existing channels into Peace River.

14. The above observations are in accord with those expressed by Dr. Blench in his report. The only deviation is my opinion that under natural conditions the break through of the Athabasca River into the Embarrass River is more likely to occur than the natural meander cutoff of the Athabasca River.

15. The lack of precise surveys of the rivers in question and their banks most likely is the cause for small diversion of opinions.

16. In view of the above arguments and the shortness of time, I would favour the following steps to be undertaken as soon as possible:

1) Survey of the rivers and their banks in the area under consideration as outlined by Dr. Blench.

2) Follow up of the conclusions reached from the surveys by scaled model studies.

3) Actions on stabilization of the Athabasca River at the bend should commence within one year or sooner.

17. Geologically speaking, the Athabasca delta is in an extremely unstable state at present, with the Athabasca River being overextended. If left under natural conditions the Athabasca River will change its course to flow into Lake Claire or Mamawi Lake in the very near future. Silting up of the lakes, and the River bypassing the delta without deposition would follow.

L. A. Bayrock

L.A. Bayrock, Ph.D.

copy #1

RIVERS - RECLAMATION - IRRIGATION - HYDRAULICS - HYDROLOGY - MODELS

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N43

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9107-120 STREET,
EDMONTON, ALBERTA
CANADA

1972

OUR FILE 72-249

YOUR FILE

April 28, 1972.

Peace-Athabasca Delta Project,
512 Baker Centre,
10025 - 106 St.,
EDMONTON, Alta.

Attention: Mr. D.M. Hornby, Director.

Dear Doug:

Athabasca River Bend near Embarras Portage.

1. I appreciated, greatly, the visit to Fort Chipewyan on 13th, 14th April with Messrs. Bayrock, Root, Yaremko and Card. Our combined knowledge proved most valuable and we soon found agreement in principle on major points; details can be settled when special hydraulic survey information becomes available. The problem of the bend is relatively simple technically, but it is linked with the situation that the Athabasca is headed for an avulsion into Mamawi Lake or Claire Lake near the bend site. Without specific figures I do not think any of us could guarantee that such an avulsion was impossible during the next few years. If it occurred I should expect a major diversion to develop within a couple of days, so the matter is serious. I shall give you opinions and recommendations under the titles THE BEND and THE AVULSION so as to avoid mixing my specific task with the related one which you may not have had cause to expect.

THE BEND.

2. See Fig. 1 (traced from one of your air photos). The ratio of flow path ABC to potential cut-off length AC is about 5.5. So, without any calculation, it is clear that the bend will cut-off with very little incentive if water can spill over paths like AC (which has an incipient channel already), or DE. The more the bend moves outward the more likely the cutoff. Experience shows that cutoffs with this large ratio can develop to almost full river size in a couple of days.

3. Until a cutoff occurs the bend will continue to move outward and one major flood is probably sufficient to cause it to breach into the Embarras River.

4. Because of the proximity of the head of the Embarras to the bend the water level in both rivers at the bend is about the same at all stages, so the breach should not cause the Embarras to start enlarging as a whole.

5. After the breach has occurred the bend should continue to move outward till it hits the left bank of the Embarras. Flow conditions will be locally disturbed (a model could indicate the flow pattern); sooner or later, the Embarras left bank will erode.

6. There are no survey data of the left levee of the Embarras. We know that it has small depressions along its edge between a and b in Fig. 2, and that definite channels start not too far (relative to a river breadth) from the edge and run to the lakes. Also Dr. Bayrock has seen water spilling over the levee during ice-jam flooding and running rapidly as a wide sheet; so an avulsion has been prevented, so far, by the frozen state of the ground plus vegetable cover.

7. If a cut, even very tiny, started through the levee in high flood so as to connect with any of the definite streams into Lakes Mamawi or Claire, and the ground were not frozen, I should expect a full-size river to develop in a couple of days.

8. The consequences of such a happening are so alarming that I recommend an immediate survey of the whole levee from a to b in Fig. 2, combined with hydraulic survey of the adjacent river and relevant extensions by an expert organisation (Alberta Research Council's River Section is the obvious one). The ground survey should include inspection of the river edge for incipient outfall streams, no matter how small, and should proceed towards the lake till obvious flat lake-shore ground is reached. The hydraulic survey should aim to establish maximum possible water-levels during thawed ground conditions and include all definite channels that could be occupied by an avulsion into a lake.

9. There are four obvious actions to take relative to the bend:

(i) Leave it alone but build banks along the left levee of the Embarras (far enough back from the river's edge to avoid the need for stone protection) in places and to elevations shown by the survey of item 8 to be necessary. If this is done the bend will cut off sooner or later -- probably sooner -- and remove danger for several decades.

- 3 -

(ii) Let it cut into the Embarras but give stone protection to the Embarras left bank.

(iii) Protect the Athabasca bend along B in Fig. 1, and give protection to the right bank of the Embarras, which is moving slightly towards the Athabasca.

(iv) Make an assisted cutoff along a path like AC in Fig. 1.

10. Regarding costs of the actions data are poor, but I estimate as follows:

(i) Survey must decide. It may show no action is needed at all.

(ii) Probably requires half the work for the Athabasca portion of (iii).

(iii) For the Athabasca about 2,000 feet of protection which, allowing for apron, would amount to covering some 60 feet of bank slope with a double-layer of 300 lb. stone of thickness about 2.5 feet. Say 10,000 cubic-yards of stone. Add cost of making bank to slope 1 upon 2 and proving a 1 foot thick underlay of pitrun gravel to act as a reverse filter. Add contingencies. For the Embarras protection I guess that length would be about 1,000 feet, so cost would be half.

(iv) Here the navigation authorities would have a say in the alignment and, if they wanted a much longer one, then the cross-section would have to be more for hydraulic reasons. I made a first estimate by specifying that the bed of the cut should be 3 feet lower than lowest annual flood and guessing that the present incipient channel had its bed only three feet below general high bank level. That gave 12 feet of cut (and I had to estimate the low flood level too, for lack of hydraulic survey data). Allowing 20 feet bed-width and 1 upon 2 sides in the probably silty material, the cross-section is 12 x 44 sq.ft. This is a tight figure, so assume 600 sq.ft. and 3,000 feet length, to give 60,000 cubic yards. If we are allowed a minimum cutoff length and ground level is lower than I guessed the amount could probably be halved.

11. The economics of a cutoff deserve consideration. First, a natural cutoff would occur sooner or later, and I think it will be sooner. When it does it has a considerable possibility of being along a path like DE which may be most awkward for navigation; we could make one to navigation requirements, though it would call for some dredging downstream through the shoals caused by the river eroding the cutoff to full size. The shoaling could be trifling if, as is likely, the material at the cutoff site is mainly fine sand and silt which would pass off in suspension.

- 4 -

Again, the cutoff would produce a drop in flood levels at the bend of about 2 feet, and this would not be lost for several decades; the saving in possible diking along the left levee of the Embarras might pay for the job. A simple model costing a few thousand dollars could demonstrate the amount of shoaling downstream of a cutoff of this type, and give some idea of rapidity of development.

12. If a cutoff is contemplated then a hydraulic survey of the whole bend and environments is required to give exact water-levels and their distribution with time during likely floods. In addition a couple of bores would be required along proposed cutoff alignments.

THE AVULSION.

13. Briefly, the hydraulic path from the vicinity of the bend to either Lake Mamawi or Lake Claire is about a sixth of that to Lake Athabasca which is at about the same level as the other two. So the imminence and violence of a cutoff, assuming Embarras spill finds a starting path, is just about the same as expected for the Athabasca bend. Presumably the Quatre Fourches are the relic of an older Athabasca River that went along Mamawi Creek. I can imagine that reversion to the old river might be good in the end, particularly if the unauthorised blocking of the Claire River at Sweetgrass were removed, but I cannot imagine anyone taking the responsibility for letting it happen by accident or giving it a blessing!

14. An interesting speculation is that the avulsion might have occurred in last summer's record high rain flood but for Lake Athabasca being lower than normal because of the dam, and the river itself being somewhat lower again because of the years of DPW dredging preventing the river from aggrading at the bend as much as it would have done naturally; the dredging could also be a cause of Lake Athabasca being a little lower.

15. I see no difficulty in checking the possibilities quantitatively if present information of all kinds (general survey, ecology and geology) are supplemented by a scientific river regime survey of the system -- which has to include the main stems of the rivers -- according to the full routine developed by the River Division of the ARC. Without this supplement the quantitative effects of various actions, their development with time, and their economics cannot be evaluated.

16. I trust this meets your immediate needs, and shall be glad to take any further action you wish.

Yours sincerely,
T. BLENCH AND ASSOCIATES LTD.

T. Blench, P. Eng.

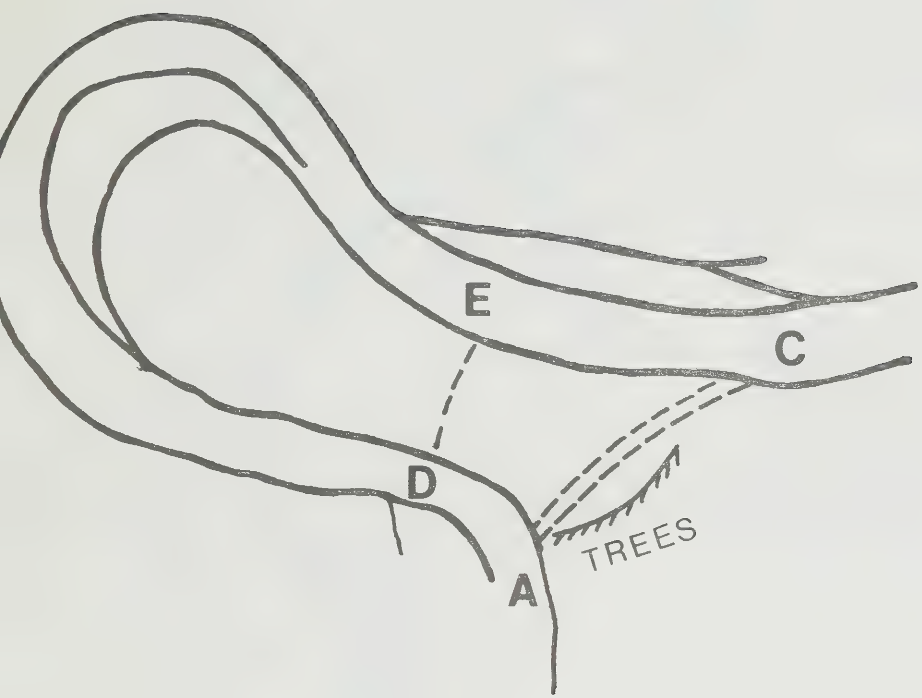


FIG. I
FROM AIR PHOTO 19/10/70
AS 1088. LINE 6.109
1:24,000

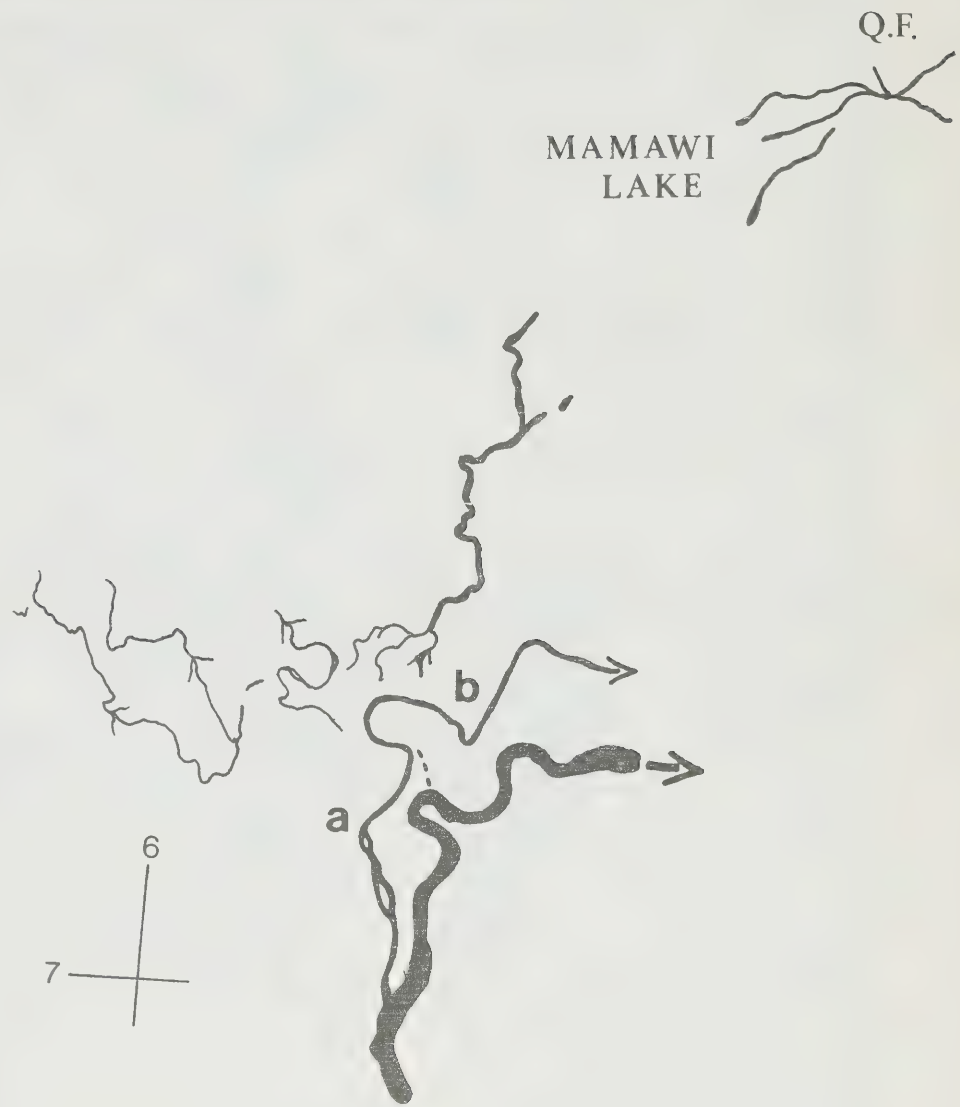
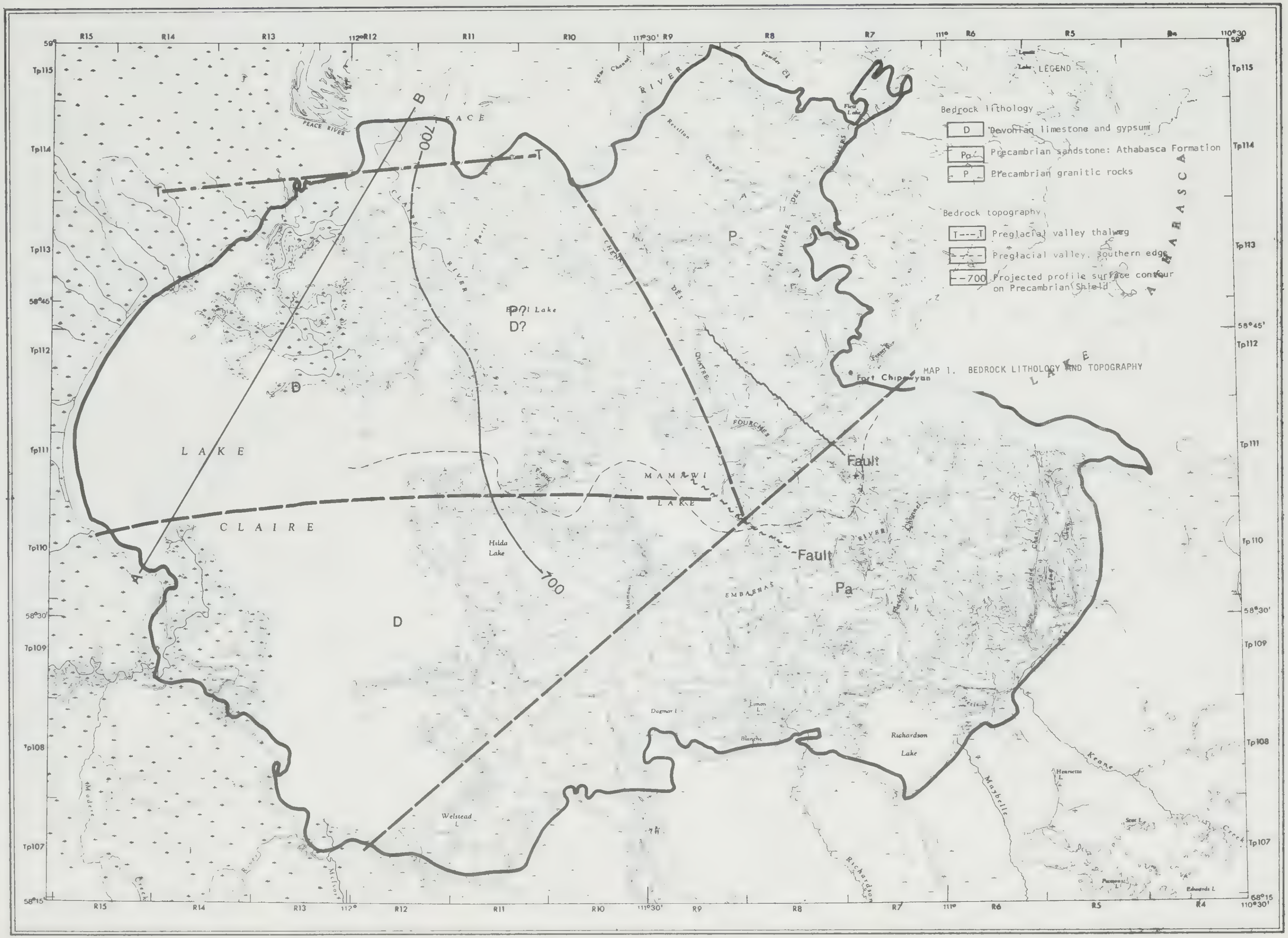
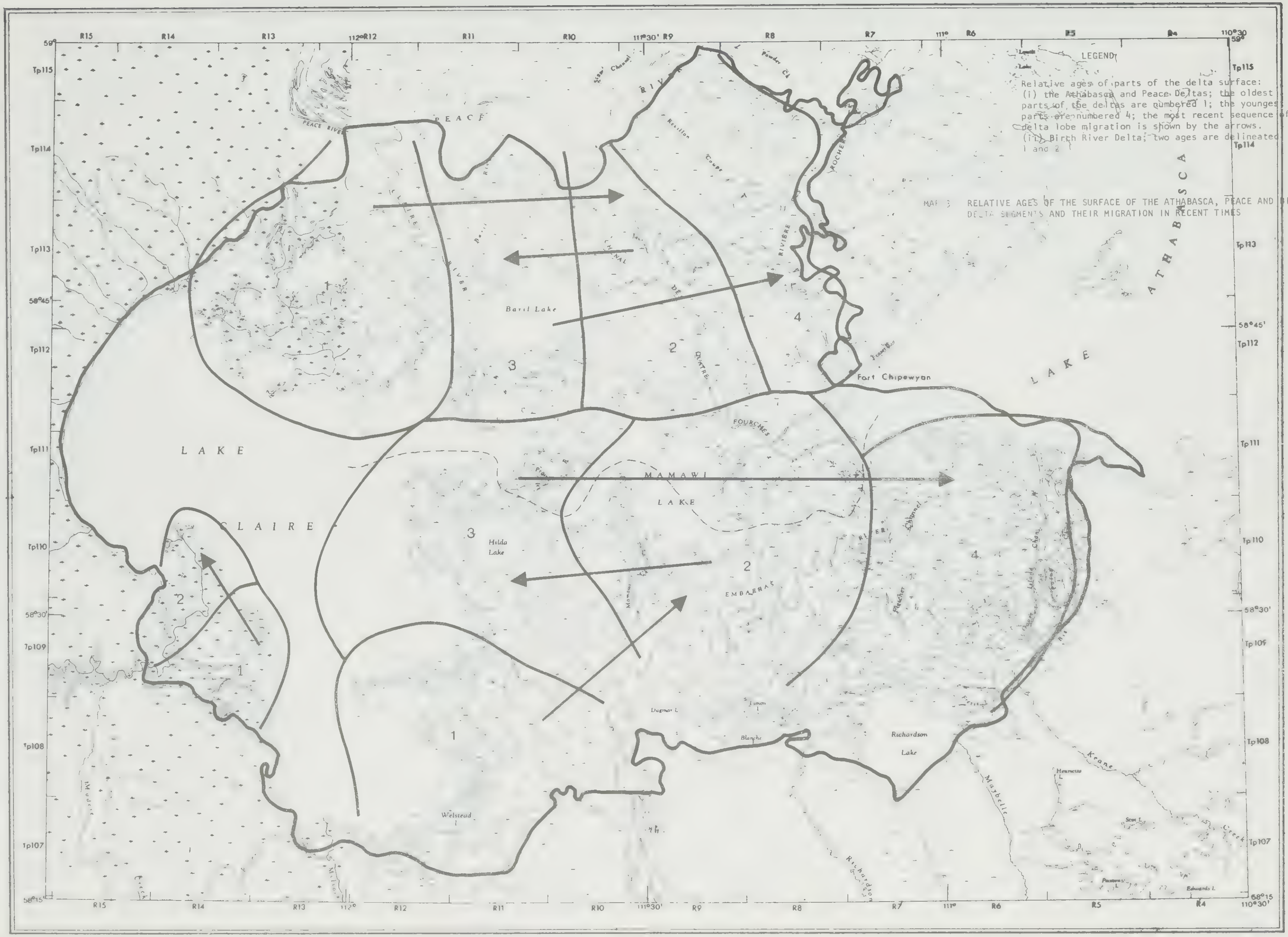


FIG 2
FROM CANADA SHEET,
FORT CHIPEWYAN
1:250,000

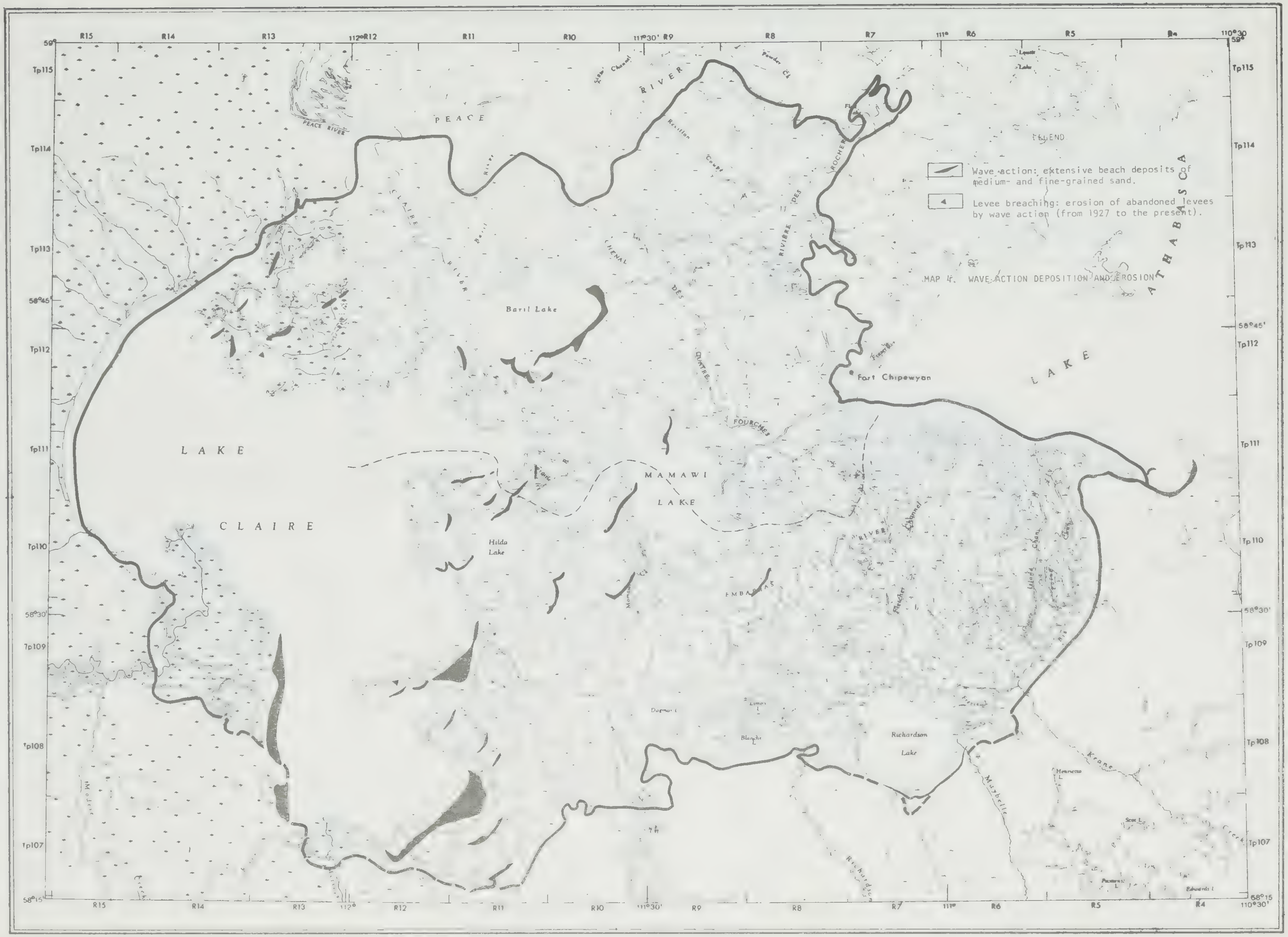


MAP 1. BEDROCK LITHOLOGY AND TOPOGRAPHY

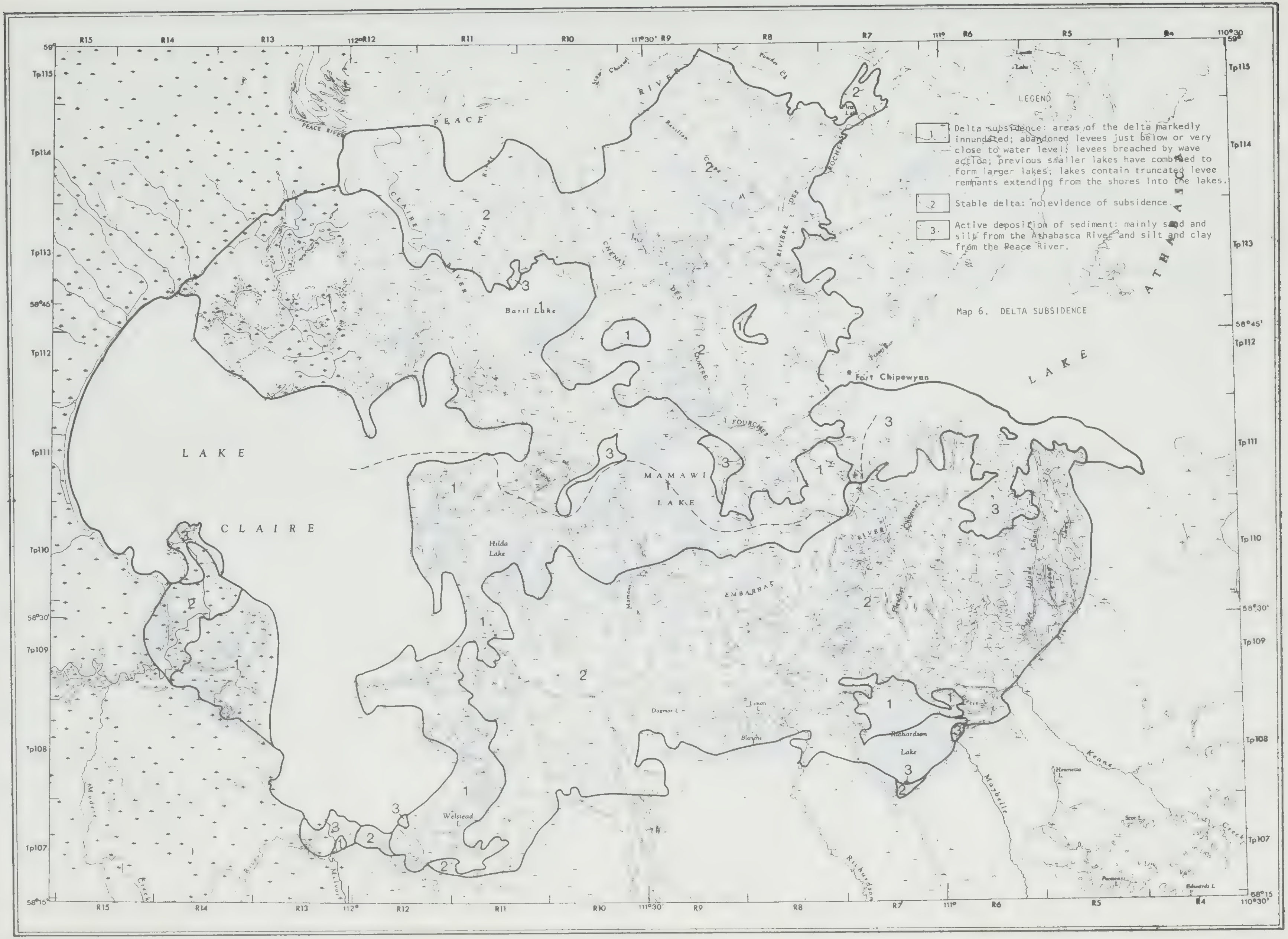
MAP 2. SAMPLE DRILLHOLE AND WATER WELL LOCATIONS



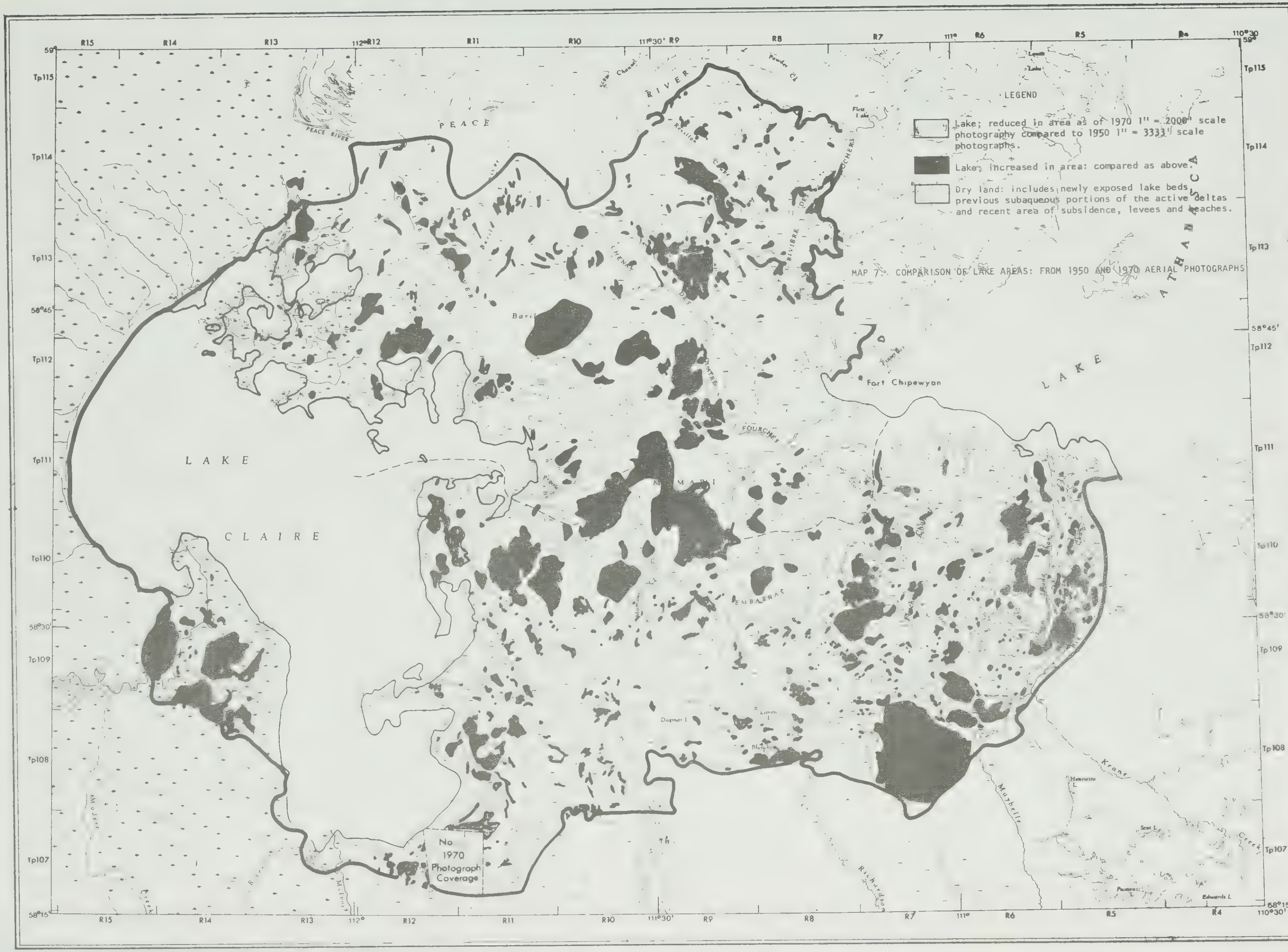
LEGEND
Relative ages of parts of the delta surface:
(i) the Athabasca and Peace Deltas; the oldest parts of the deltas are numbered 1; the youngest parts are numbered 4; the most recent sequence of delta lobe migration is shown by the arrows.
(ii) Birch River Delta; two ages are delineated 1 and 2
MAP 3 RELATIVE AGES OF THE SURFACE OF THE ATHABASCA, PEACE AND BIRCH RIVER DELTA SEGMENTS AND THEIR MIGRATION IN RECENT TIMES
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
PEACE RIVER
RIVIERE DES ROCHERS
CHENAL DES QUATRE FOURCHES
CLAIRE RIVER
EMBARRAS RIVER
Fort Chipewyan
Baril Lake
Hilda Lake
Richardson Lake


LEGEND
Wave action: extensive beach deposits of medium- and fine-grained sand.
Levee breaching: erosion of abandoned levees by wave action (from 1927 to the present).
MAP 4. WAVE ACTION DEPOSITION AND EROSION
LAKE ATHABASCA
LAKE CLAIRE
MAMAWI LAKE
PEACE RIVER
RIVIERE DES ROCHER
CHENAL DES QUATRE FOURCHES
CLAIRE RIVER
Baril Lake
Hilda Lake
Richardson Lake
Fort Chipewyan
EMBARRAS RIVER
Maybelle
Krone
Powder Ck
Revillon Coupé
Fletcher Channel
Mamawi Ck
Tp115
Tp114
Tp113
Tp112
Tp111
Tp110
Tp109
Tp108
Tp107
R15
R14
R13
R12
R11
R10
R9
R8
R7
R6
R5
R4
59°
58°45'
58°30'
58°15'
112°
111°30'
111°
110°30'

MAP 5. RATE OF SEDIMENTATION



Map 6. DELTA SUBSIDENCE



MAP 7. COMPARISON OF LAKE AREAS: FROM 1950 AND 1970 AERIAL PHOTOGRAPHS

SECTION O

SECTION O

PEACE-ATHABASCA DELTA PROJECT

REPORT

ON

WATER QUALITY

1971-1972

Submitted to:

Director, Peace-Athabasca Delta Project
Edmonton, Alberta

Prepared by:

Western Region
Water Quality Branch
Calgary, Alberta

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APPENDICES

Appendix A. Chemical and physical properties of the surface waters of the Athabasca Delta complex, Alberta.

Appendix B. Chemical properties of the surface waters of the Athabasca Delta complex under ice cover.

Appendix C. Exchangeable and acid soluble analysis of the Athabasca Delta lake sediments.

Appendix D. Chemical loadings and chemical balances.

SUMMARY

The results of the water quality study on the Peace-Athabasca Delta showed from the monitoring program that the rivers and streams inflowing to the delta with local drainage basins contained more total dissolved solids per unit volume of water than the streams inflowing from the west, and that the inflowing streams draining the Canadian Shield contained the least total dissolved solids per unit volume.

The annual discharge-weighted averages of total dissolved solids showed the streams with local drainage basins, the Birch and McIvor Rivers, to contain 240 and 360 mg/l, respectively. The highest discharge-weighted averages occurred during the low discharge periods but the McIvor River showed a higher total discharge-weighted average during the high discharge period than during the intermediate discharge period, whereas the reverse was true for the Birch River. The annual discharge-weighted average for the stream from the west, the Athabasca River, was 216 mg/l. This river also contained the highest discharge-weighted averages during the low discharge period and the lowest discharge-weighted averages during the high discharge period.

Lake Claire showed a high of 3837 mg/l for a total volume-weighted average during the low discharge period and a low of 422 mg/l for a total volume-weighted average during the high discharge period. Lake Mamawi was dry during the low discharge period but showed a higher total volume-weighted average

during the high discharge period than during the intermediate discharge period. Lake Athabasca showed relatively equal total volume-weighted averages for the low and intermediate discharge periods, approximately 96 mg/l, and 48 mg/l total volume-weighted averages for the low discharge periods.

Flow data was not available for the Riviere des Rochers during the low discharge period, but this river showed total discharge-weighted averages of 140 mg/l for the intermediate discharge period and 159 mg/l for the high discharge period. These values when compared to such values for Lake Athabasca and the Athabasca River indicate the major portion of the flow in this river is Athabasca River waters.

The ice cover water quality survey conducted in 1971 showed Lakes Baril, Mamawi, Hilda, and Richardson to be frozen throughout, and Lake Claire to contain four inches of water under the ice in the deepest portion of the lake only. The shallow water, south-west, portion of Lake Athabasca was frozen throughout for a distance of approximately three miles into the lake.

The results of this survey showed Lake Claire to be deviod of dissolved oxygen and to contain dissolved salts in the order of 2,800 mg/l. The inflowing streams to this Lake, the Birch and McIvor Rivers, contained dissolved oxygen in order of 3 mg/l and 4.5 mg/l and dissolved salts in the order of 1,000 mg/l and 2,400 mg/l, respectively. A dissolved oxygen survey of the Birch River conducted during the winter of 1972 showed levels of less than 2 mg/l for a distance of 15 miles upstream from its mouth.

The Lake Athabasca results of this survey showed quite conclusively that the waters from the Canadian Shield (75 mg/l dissolved salts) do not mix with water from the west, the Athabasca River with a dissolved salt content of 225 mg/l. The dissolved oxygen levels in Lake Athabasca waters under the ice were shown to be in the order of 8 mg/l.

The ice cover survey results also showed that Lake Claire waters contained relatively high concentrations of calcium, magnesium, sodium, potassium, bicarbonates, sulfates, nitrates and phosphates. Whereas the waters of Lake Athabasca contained relatively low concentrations of these elements. In addition, abnormally high concentrations of barium, boron, carbon, copper, iron, lithium, manganese, and strontium were also found in Lake Claire waters. The concentrations of these minor elemenets were shown to be insignificant in Lake Athabasca waters.

The preliminary lakes sediment survey results showed that 40 to 70 percent calcium, 6 to 10 percent magnesium, 30 to 35 percent sodium, 30 to 40 percent manganese and 10 to 25 percent potassium of the total acid soluble quantities of these elements were held in exchangeable form on the lake bottom sediments. The results also showed that quantities of these elements present in the sediments in order of decreasing values were calcium, magnesium, potassium, manganese, and sodium.

The chemical loading results for 1971 water year show that the contributions of total dissolved salts to Lake Claire were 208 x 10^3 metric tons from the Birch River and 56.3 x 10^3 metric tons from the McIvor River, making a total of 264.3 x 10^3 metric tons from these sources. Lake Claire was shown to

discharge 174 x 10^3 metric tons of total dissolved solids to the Prairie River, and Chenal des Quatre Fourches contributed 211 x 10^3 metric tons of dissolved solids to Mamawi Lake. Also, during this period Lake Mamawi discharged to the Chenal des Quatre Fourches 173.9 x 10^3 metric tons of total dissolved solids.

The calculated results, based on the assumption outlined in the chemical loading section of this report, for the hypothetical 5-year sequence for the Lake Claire-Lake Mamawi Basin System show that this basin system will receive 2,071.7 x 10^3 metric tons and discharge 1,351 x 10^3 metric tons of total dissolved solids.

The chemical balance results calculated from the chemical loading data show that Lake Claire received 264,247.9 metric tons, discharged 174,089 metric tons, and retained 90,158.8 metric tons of total dissolved solids during 1971, and that Lake Mamawi received 211,270.9 metric tons, discharged 173,888.2 metric tons, and retained 37,382.6 metric tons of total dissolved solids during the same period.

The chemical balance results for the hypothetical 5-year sequence for the Lake Claire-Lake Mamawi Basin System show that this system will receive 2,107,680.3 metric tons, discharge 1,351,250.7 metric tons, and retain 720,429.5 metric tons of total dissolved solids over the 5-year period.

INTRODUCTION

This water quality study of the Peace-Athabasca Delta was initiated in response to a request from the Director, Peace-Athabasca Delta Project - a Canada-Alberta-Saskatchewan project conceived to investigate local concern that a decline in water levels in the delta complex, brought about by controls on the Peace River, poses a threat to the delta's eco-system.

This study, one of a number of studies, was designed to determine:

(1) the unknown basic chemical constituents of the waters of inflowing and outflowing streams to the delta and of the waters of lakes in the delta area during each of the seasons over the 15 month period from March 1971 to June 1972;

(2) to calculate the chemical balance of the water regime of the delta for the purpose of predicting chemical build-up in lake waters during natural and controlled water levels; and

(3) to make reference to possible harmful environment effects attributable to chemical quality build-up in lake waters as a result of water level controls.

This report discusses the factors affecting the chemistry of the waters in the delta complex, the significance of the various water parameters measured, the results obtained from the study and the chemical loadings to the system. It provides a chemical balance of the water system with an accuracy dependent on the accuracy of the water quantity balance. And finally it provides conclusions from the study results and makes recommendations based on the findings.

STUDY OBJECTIVES

The objectives of this study may be defined as:

1. To determine the quality of the waters in the delta complex during the winter, spring, summer, and fall seasons.
2. To determine the chemical constituents and the concentrations of the constituents in inflow/outflow streams and lakes of the delta complex during the four seasons of the year.
3. To calculate the chemical loadings to and the chemical balance of the delta water system.

FACTORS AFFECTING WATER QUALITY IN THE DELTA

The chemical principles and processes that affect water quality are too many and varied to discuss at this time but the manner in which the processes operate, however, and their relative importance to the eco-system are controled by factors of a nonchemical nature. The significance of these nonchemical factors in natural water chemistry as related to the delta are here considered.

Geology

The ultimate source of most dissolved chemical constituents in water is the mineral assemblage in rocks near the land surface.

The Peace-Athabasca delta is located in the northern portion of the Western

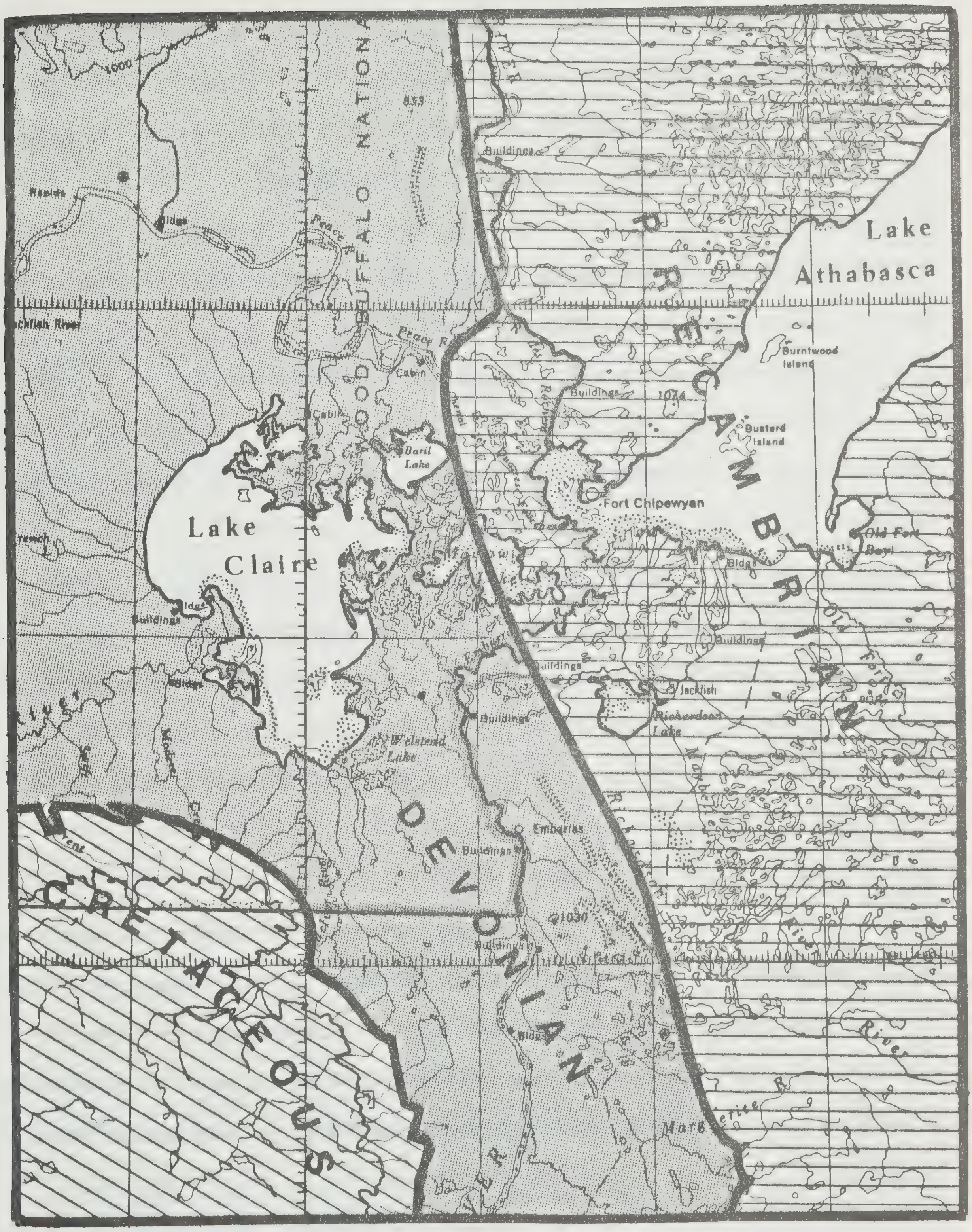


Fig. 1 Geology of Peace-Athabasca Delta

Canadian Sedimentary Basin and is underlain by halite-bearing stratigraphic units of Middle Devonian, Elk Point Group which dip southeast, away from the Canadian Shield (Figure 1). Halite comprises approximately 5.7 percent of the rocks of the Middle Devonian, Elk Point Group.

Surface evidence of these halite-bearing stratigraphic units in the northern portion of the Western Canadian Sedimentary Basin is found in solution collapse structures and saline springs.

The hydraulic head in this region causes fresh waters from the surface to penetrate to Middle Devonian rocks and results in solution of the halites. The saline formation waters then move updip, discharging into the rivers flowing from the south and west or as springs along the valley of the Athabasca River. LaSaline is an example of such a spring which is found 26 miles north of the Town of Fort McMurray and has a total dissolved solids content of 71,400 milligrams per liter of solution (Hitchon, et al 1969).

Climate

The processes of weathering are strongly influenced by temperature and by the amount and distribution of precipitation. However, the influence of climate on water quality goes beyond these effects. Climatic conditions tend to produce characteristic plant communities and soil types, and the composition of waters draining from such areas can be considered as products of ecologic balance.

The semi-arid climate of the Peace-Athabasca delta consisting of long severe winters and relatively short moderately hot and dry summers is generally

characterized by alternating wet and dry periods. Such conditions favor weathering reactions that produce considerably larger amounts of soluble inorganic matter at some periods of the year than at other periods. Streams in this area tend to fluctuate greatly in volume of flow, and the water quality tends to have a wide range of chemical composition. This is particularly so during the spring snow-melt period of mid May to July.

In addition, direct runoff during the snow-melt period is severe and results in large quantities of mineral solid being carried into streams to react chemically with solutes, thus also affecting the chemical composition of the water.

Soils

Many of the processes that form soils are the same ones that control natural-water composition.

Precipitation that reaches the soil surfaces ultimately appears as runoff or as ground water that has spent considerable time in contact with soil.

The chemical composition of soil moisture (ground water) is influenced by many factors, such as the solution or alteration of silicates and other minerals, precipitation of sparingly soluble salts, selective removal and circulation of elements by plants, biochemical reactions producing carbon dioxide, sorption and desorption of ions by mineral and organic surfaces, and concentration of solutes by evapotranspiration.

The soils surrounding the delta, in general, contain considerable quantities

of carbonates as shown by a base saturation in the range 90-100 percent. These soils, however, contain only small amounts of sodium and chloride ions. (Lindsay, et. al, 1961). Thus, streams flowing through these soil areas can dissolve sufficient quantities of calcium and magnesium carbonates to account for the hardness and alkalinity of the waters entering the delta complex but would not account for the sodium chloride content of these waters.

An investigation of the ground water in the west end of the delta complex showed the water, at depths of 140 to 160 feet, to contain sodium, sulfate, and chloride in ranges between 154 and 193 mg/l, 1300 and 1650 mg/l, and 200 and 320 mg/l, respectively. These waters entering streams through bank seepage or as groundwater springs would account for the sodium, sulfate and chloride content of the river waters entering the delta complex from the south and west.

Drainage

Two distinct drainage basins are associated with the delta complex: the drainage basins of rivers which enter the delta complex from the south and west, and the lakes and rivers with drainage basins entirely within the Canadian Shield which enter the delta complex from the east.

Surface water quantity data (Anonymous, 1969) indicate that the major portion of the flow into the delta complex originates in rivers and streams entering from the south and west. A small portion of the flow enters from the east and the smallest portion from a few streams with small local drainage basins.

The lakes and rivers with drainage basins entirely within the Canadian Shield

have total dissolved solids contents of less than 100 mg/l, compared to a range of 100-200 mg/l for all major rivers which predominantly drain over the sedimentary rocks of the Western Canadian Sedimentary Basin. The smaller streams entering the delta complex from the west and south that drain over Middle Devonian sediments have total dissolved solids contents of 200-500 mg/l.

The total dissolved solids contents of the water bodies in the delta complex area are, therefore, governed by the source of the inflowing waters. Thus, their total chemical content can be quite varied depending on the recharge source.

SAMPLING LOCATIONS AND SAMPLING FREQUENCIES

Water Quality Monitoring Program

The descriptions of sampling locations, their latitude and longitude, and the frequency of sampling for each location are contained in Table I.

Sampling stations are illustrated as to geographical locations in Figure 2.

Water Quality Ice Cover Survey

The descriptions of sampling locations, their latitude and longitude are contained in Table II. These locations were sampled on a once only basis.

Sampling stations are illustrated as to geographical locations in Figure 3.

Lakes Sediment Survey

The description of sampling locations, their latitude and longitude are contained in Table III. These locations were sampled on a once only basis. Sampling stations are illustrated as to geographical locations in Figure 2.

Fig. 2 Location map of the Water Quality Monitoring Program, Dissolved Oxygen Survey, and Sediment Survey Stations.

TABLE I

WATER QUALITY MONITORING STATIONS

Station Name	Station Location	Latitude	Longitude	Frequency
Peace River	at Peace Point	59°07'20"	112°27'30"	Monthly
Athabasca River	at Embarras Airport	58°11'98"	111°23'12"	"
Birch River	near mouth	58°32'18"	112°15'6"	"
Richardson River	near mouth	58°25'	111°23'12"	"
Rivere des Rochers	at outlet Athabasca Lake	58°49'36"	111°16'48"	"
McFarlane River	at outlet Davy Lake	58°58'24"	108°10'30"	"
Fond du Lac River	at outlet Black Lake	59°10'	105°	"
McIvor River	near mouth	58°18'6"	112°1'48"	"
Old Fort River	near mouth	58°36'18"	110°28'24"	"
Harrison River	near mouth	58°41'	110°20'24"	"
William River	near mouth	59°6'54"	109°16'54"	"
Lake Claire	Northwest	58°39'30"	112°21'	"
Lake Claire	Center	58°36'	112°	"
Lake Claire	South	58°25'	112°	"
Lake Athabasca	near Ft. Chipewyan	58°43'30"	111°	"
Lake Athabasca	at Alta-Sask. border	59°9'0"	110°	"
Lake Athabasca	South of Uranium City	59°14'48"	108°39'36"	"
Lake Athabasca	near Fond du Lac	59°20'	107°10'	"
Crown Creek	at mouth	58°36'18"	110°29'30"	Periodic
Clarence Creek	at mouth	58°42'42"	110°17'36"	"
Quatre Fourches	north of jnt. of Forks	58°39'42"	111°18'54"	Monthly
Dunville Creek	near mouth	58°59'18"	109°5'42"	Periodic
Maybelle River	near mouth	58°22'54"	110°57'36"	Monthly
Keane Creek	near mouth	58°26'6"	110°52'12"	Periodic
Serwatka	near mouth	58°59'18"	109°4'6"	"

TABLE II

LOCATIONS - WINTER ICE SURVEY

Source	Map Reference	Latitude	Longitude	Analysis: Field	Analysis: Calgary Lab.
Lake Claire	1-7	58°38'48"	112°10'48"	X	
	1-9	58°38'20"	112°11'18"	X	X
	1-11	58°36'	112°14'36"	X	
	2-7	58°35'6"	112°10'48"	X	
	2-11	58°35'42"	112°04'12"	X	X
	2-13	58°36'18"	112°	X	
	8-3	58°27'18"	111°59'18"	X	
	8-5	58°27'48"	111°59'6"	X	
	8-15	58°31'18"	111°57'12"	X	X
	10-5	58°36'12"	112°17'12"	X	
	10-6	58°36'30"	112°17'30"	X	X
Lake Athabasca	21-1	58°42'0"	111°03'30"	X	
	21-2	58°42'24"	111°03'18"	X	
	21-3	58°43'0"	111°03'0"	X	
	21-4	58°43'30"	111°02'42"	X	
	21-5	58°44'0"	111°02'18"	X	
	21-6	58°44'30"	111°01'42"	X	X
	21-7	58°45'0"	111°01'30"	X	
	21-8	58°45'30"	111°01'6"	X	
	22-1	58°46'0"	111°00'00"	X	
	22-2	58°45'30"	110°59'42"	X	
	22-3	58°45'0"	110°59'18"	X	
	22-4	58°44'30"	110°58'54"	X	
	22-5	58°44'0"	110°58'36"	X	
	22-6	58°43'30"	110°58'24"	X	
	22-7	58°43'0"	110°58'6"	X	
	22-8	58°42'30"	110°57'48"	X	
	22-9	58°42'0"	110°57'36"	X	
	23-1	58°41'48"	110°46'48"	X	
	23-2	58°42'18"	110°46'48"	X	
	23-3	58°42'48"	110°46'48"	X	

TABLE II (cont'd)

Source	Map Reference	Latitude	Longitude	Analysis Field	Analysis Calgary Lab.
Lake Athabasca	23-4	$58^{o}43'18''$	$110^{o}46'48''$	X	X
	23-5	$58^{o}43'48''$	$110^{o}46'48''$	X	
	23-6	$58^{o}44'18''$	$110^{o}46'48''$	X	
	23-7	$58^{o}44'48''$	$110^{o}46'48''$	X	
	23-8	$58^{o}45'24''$	$110^{o}46'48''$	X	
	23-9	$58^{o}46'00''$	$110^{o}46'48''$	X	
	24-1	$58^{o}46'18''$	$110^{o}40'18''$	X	
	24-2	$58^{o}45'36''$	$110^{o}39'54''$	X	
	24-3	$58^{o}45'00''$	$110^{o}39'36''$	X	
	24-4	$58^{o}44'12''$	$110^{o}39'6''$	X	
	24-5	$58^{o}43'30''$	$110^{o}38'45''$	X	X
	24-6	$58^{o}42'42''$	$110^{o}38'18''$	X	
	24-7	$58^{o}42'00''$	$110^{o}37'54''$	X	
	24-8	$58^{o}41'18''$	$110^{o}37'24''$	X	
	24-9	$58^{o}40'38''$	$110^{o}37'6''$	X	X
	24-10	$58^{o}39'48''$	$110^{o}36'42''$	X	
	24-11	$58^{o}39'12''$	$110^{o}36'12''$	X	
	25-1	$58^{o}49'30''$	$110^{o}49'18''$	X	
	25-2	$58^{o}49'18''$	$110^{o}48'45''$	X	
	25-3	$58^{o}49'10''$	$110^{o}47'54''$	X	X
	25-4	$58^{o}48'60''$	$110^{o}47'6''$	X	
	25-5	$58^{o}48'50''$	$110^{o}46'15''$	X	
	25-6	$58^{o}48'42''$	$110^{o}45'30''$	X	
	25-7	$58^{o}48'33''$	$110^{o}44'54''$	X	
Birch River	41-2) 41-3) 41-5)	$58^{o}26'30''$	$112^{o}18'42''$	X X X	
McIvor River	42-5) 42-6) 42-7)	$58^{o}17'45''$	$112^{o}01'15''$	X X X	
Quatre Fourches	43-2) 43-4) 43-6)	$59^{o}39'21''$	$111^{o}17'54''$	X X	
	46-7) 46-4) 46-9)	$58^{o}38'48''$	$111^{o}18'15''$	X X X	

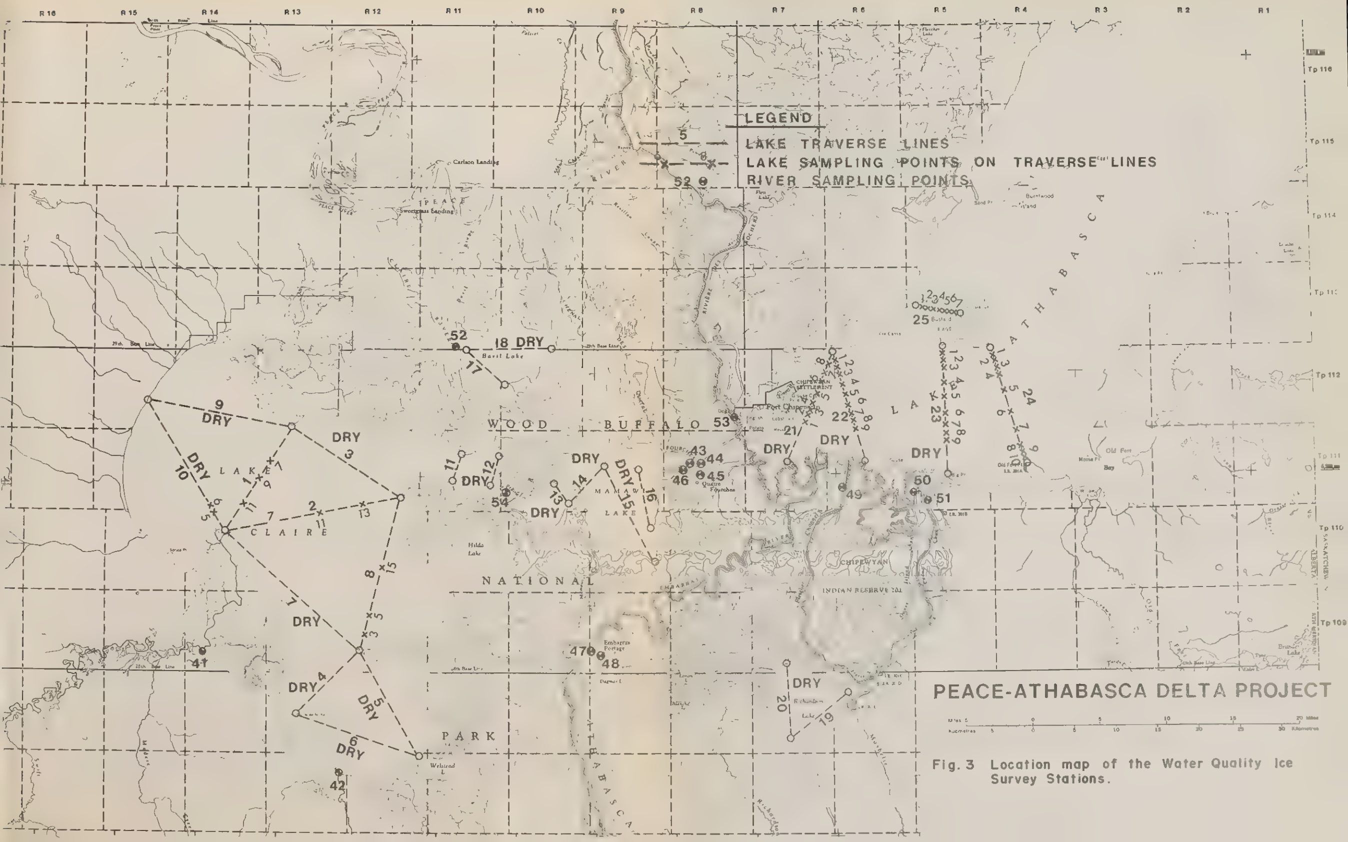
TABLE II (cont'd)

Source	Map Reference	Latitude	Longitude	Analysis Field	Analysis Calgary Lab.
Quatre Fourches	44-4) 44-5) 44-7)	58°39'6"	111°16'51"	X X X	
	45	58°38'42"	111°16'45"	Dry - significant - i.e. Nothing from Lake Athabasca west into Mamawi in winter in this channel. However, note 44-4 to 44-7.	
Embarras River	47-5) 47-6) 47-8)	58°27'00"	111°29'48"	X X X	
Athabasca River	48-5) 48-7) 48-9)	58°26'24"	111°29'00"	X X X	
Fletcher Channel	49-9) 49-11) 49-12)	58°37'36"	110°58'48"	X X X	
Goose Isl. Channel	50-4) 50-8) 50-11)	58°37'18"	110°50'00"	X X X	
Big Point Channel	51-3) 51-5) 51-7)	58°36'24"	110°48'24"	X X X	
Claire River	52-2) 52-4)	58°46'20"	111°46'33"	X	
Ride Roches	53-6) 53-8)	58°42'15"	111°12'12"	X	
Prairie River	54-4) 54-5) 54-6)	58°37'36"	111°40'42"	X X X	

TABLE III

SEDIMENT SURVEY

Source	Location	Latitude	Longitude
Lake Athabasca	West	58°42'24"	110°03'18"
Lake Athabasca	East	58°44'30"	110°58'54"
Lake Athabasca	Middle	58°44'24"	110°53'18"
Baril Lake	Middle	58°46'12"	111°41'00"
Claire Lake	Middle West	58°36'12"	112°17'12"
Claire Lake	Middle East	58°37'42"	111°58'00"
Claire Lake	South	58°21'48"	111°59'30"
Mamawi Lake	West	58°37'42"	111°32'54"
Mamawi Lake	East	58°36'20"	111°23'48"



PEACE-ATHABASCA DELTA PROJECT

Fig. 3 Location map of the Water Quality Ice Survey Stations.

SAMPLING PROCEDURES AND SAMPLE HANDLING

Water Quality Monitoring Program

Water quality stations for this program were established by personnel from the Western Region, Water Quality Branch, in cooperation with members of the Peace-Athabasca Delta Project staff to ensure the results would satisfy the study objectives.

Water Quality personnel surveyed the delta area by fixed wing aircraft and helicopter to pin-point the actual sites.

The initial round of samples were collected by Water Quality personnel. A member of the Peace-Athabasca Delta Project based in Fort Chipewyan participated in the initial collection of samples to learn proper sampling techniques and procedures. All following monthly collection of water samples, field testing, etc. were handled by Peace-Athabasca Delta Project personnel.

Sampling Procedures

A metal sampler with bottle designed to obtain an integrated sample of water was used to collect the samples at all locations. This method is widely recognized as the best available for water quality sampling.

The sample was taken by dropping the opened bottle, affixed to the metal sampler, into the water and as it filled was allowed to sink to the bottom of the stream or lake. When the bottom was reached the sampler was pulled

to the surface. If the bottle was not filled the procedure was repeated until sufficient sample was collected. This procedure assures that portions of water at all depths were obtained.

The sample bottles used were two liter polyethylene bottles. These bottles had hard plastic tops containing a specially designed polyethylene liner. Use of this type of bottle and top ensured negligible contamination.

It should also be noted that sampling bottles, as received by the sampling crew, were pre-cleaned in the Calgary laboratory and were ready for field use.

Because the elements to be analysed are present in minute quantities in water, extreme care was taken not to contaminate the neck of the bottle and cap while sampling. The bottles and caps were rinsed three times before filling with the sample. The cap with a polyethylene seal was then secured tightly to prevent leakage during shipping. Also, the bottle was filled to the neck only, leaving room for expansion.

As smaller samples were required for on site analysis smaller bottles were filled from the sample bottle in the metal sampler immediately upon collection of the sample.

Sampling from shore or by wading and sampling directly into the sampling bottle was practiced only where necessary.

Sampling from shore is not altogether satisfactory because of shore contamination, still water, etc. However, due to the small size of certain streams

in this program this technique was unavoidable.

When using this method, after rinsing as described in the previous method, the bottle was held below the surface until filled. It was then drained to within two inches of the top and capped. In addition, it was deemed preferable to remove the plastic cap under the water to prevent surface scum, dirt, or dust from entering the bottle.

Lake samples were obtained by sampling from the floats of the aircraft. In the case of stream samples all were obtained from the fastest flowing portion of the stream.

Under winter ice conditions, the procedure as described above for collecting samples with the metal sampler was followed after the initial drilling or cutting of a suitable size hole in the ice.

For all locations one and/or two liter samples were obtained and shipped for analysis to the Calgary laboratory.

Sample Handling

At each location the following analyses were performed on each sample collected:

(a) Temperature - see Analytical Methods and Techniques for description.

(b) pH - " " " " " " "

(c) Conductance - " " " " " " "

(d) Dissolved Oxygen - The sample for D.O. determination was prepared at the time of sampling by carefully pouring a portion of sample into a standard size 300 mg B.O.D. bottle

ensuring that no air bubbles were introduced. The regular procedure for the addition of manganese sulfate and alkali-ozide mixture was followed at the time of sampling. The sample was left in this condition and the test completed as described under Analytical Methods and Techniques in Fort Chipewyan.

Each sample was carefully identified at the time of sampling and the following information was recorded and forwarded to the Calgary laboratory:

(a) Location and source: identified sample site and station number.

(b) Date: time, day, month, and year sample taken.

(c) Bottle Number: correlate sample to rest of identification. Permanent waterproof numbers are permanently placed on each bottle.

(d) Water level: readings were recorded at the time of sampling at locations having gauges excepting those having continuous gauges.

(e) Collector: signature of collector.

(f) Field measurements: temperature, pH, conductance, D.O.

Facilities for proper filtering of samples were not available at the time of sampling in Fort Chipewyan. As a result, sampling schedules were arranged to have samples collected and placed on commercial aircraft to arrive at the Calgary laboratory within twenty-four hours of collection.

Water Quality Ice Cover Survey

Sampling Procedures and Sample Handling

Initial determination of sampling procedures, field testing, and sample handling were established by personnel from the Western Region, Water Quality Branch cooperatively with Canadian Engineering Service (under contract to the Peace-Athabasca Delta Project).

Canadian Engineering Services personnel were trained in the Calgary laboratory for the proper techniques on sampling, field analysis for pH, temperature, conductance, and dissolved oxygen, and proper sample handling.

These procedures are identical to those described in the previous section. "Water Quality Monitoring Program."

Lake Sediment Survey

Sampling Procedures

Exclusive use of helicopter was required as the Delta had experienced a cold snap prior to sampling. Approximately one to six inches of ice was found at all locations except the two eastern locations of still ice-free Lake Athabasca. As such, holes were chopped very close to the floats of the helicopter and sampling performed from the floats or very close to the floats.

The sediment sampler used was a jaw-type, spring loaded "Wildlife Supply Co." model 196 sediment sampler. The sample was lowered through the ice hole until it rested on the lake bottom. A heavy weight was released which travelled down the rope attached to the sampler releasing the jaws.

Approximately one pound of sediment was caught by the sampler representing the top 2-4 inches of bottom sediments.

Sample Handling

The sampler was brought to the surface and the contents transferred to a wide mouth polyethylene bottle. The samples were then shipped via commercial aircraft for delivery within twenty-four hours to the Calgary Laboratory.

ANALYTICAL METHODS, TECHNIQUES, AND LIMITS OF ACCURACY

WATER QUALITY MONITORING PROGRAM AND WATER QUALITY ICE COVER SURVEY

A brief description of the methods used are detailed below. References to the methods are cited following these brief descriptions.

All results are expressed as mg/l unless otherwise stated.

Conductivity	-	Measurement made using a platinum electrode type conductivity meter. Values corrected to 25° centigrade and expressed as umho/cm. (1)*
Turbidity	-	Measurement made with Hach model 2100 turbidimeter. Measurements are based on the amount of light reflected by particles. Results are expressed in Jackson turbidity units. (2)
Temperature	-	Measurements made with mercury-filled thermometer (-10 to 50° centigrade range - 300 mm length thermometer). Results expressed in degrees centigrade. (1)
pH	-	Electrometric method using pH meter equipped with glass and saturated calomel electrodes. Results expressed in pH units. (1)
Alkalinity (Total)	-	Potentiometric titration with standard acid solution. Alkalinity expressed as $CaCo_3$. (1)
Calcium (Dissolved)	-	Titration with ethylenediamine-tetraacetic acid (E.D.T.A.) and eriochrome blue ad indicator. (2) (Treatment of sample for dissolved analysis follows these descriptions).

*Numbers in parenthesis refer to references as indicated.

Magnesium (Dissolved)	-	Calculated from the values of Total Hardness and dissolved calcium. $mg = (\text{Total Hardness}) \times 0.01998 - \text{Calcium} \times 0.0499) \times 12.16.$ (2)
Hardness (Total)	-	Titration with E.D.T.A. using eriochrome Black T as indicator. Values expressed as $CaCo_3$. (1)
Sodium (Dissolved)	-	Flame photometry by internal-standard measurement on auto analyser. (2)
Potassium (Dissolved)	-	Flame photometry by internal standard measurement on auto analyser. (2)
Iron (Dissolved)	-	Colourimetric on auto analyser with tripyridyl-s-triazine. (2)
Manganese (Dissolved)	-	Atomic absorption determination by direct aspiration. (2)
Copper (Dissolved)	-	Determination by atomic absorption after solvent extraction. (2)
Silica	-	Colorimetric heteropoly blue method on auto analyser with ammonium molybdate and aminonaphtholsulfonic acid. (2) Results expressed as SiO_2.
Nitrate - Nitrogen (Dissolved)	-	Colourimetric on auto analyser. Nitrate is reduced by cadmium and the resulting nitrite is determined by diazotizing with sulphanilamide and naphthylamine dihydrochloride. Thus both nitrate and nitrite are determined. (2)
Total Kjeldahl Nitrogen	-	Organic nitrogen is converted to an ammonium salt by digestion with sulphuric acid. Ammonia is then distilled from an alkaline medium and absorbed in boric acid. The ammonia is determined by titration with standard acid. This test includes the organically bound nitrogen and ammonia sample. The test is performed on a shaken sample. (1)
Chloride (Dissolved)	-	Colourimetric on auto analyser with ferric ammonium sulphate and mercuric thiocyanate. (2)
Phosphate (Ortho Dissolved)	-	Colourimetric on autoanalyser with ammonium molybdate and stannous chloride. (2)

Sulphate (Dissolved)	-	Sample is passed through a strong cation exchange resin (Ambelite IR-120 or equivalent). Sulphate is titrated in an alcoholic solution under controlled acid conditions with a standard barium chloride solution using thorin as the indicator. (2)
Phosphate (Total)	-	Colourimetric on auto analyser with ammonium molybdate and stannous chloride after 30 minutes in an autoclave with sulfuric acid and potassium persulphate. Determination is done on a shaken sample. (2)
Fluoride (Dissolved)	-	Determined with fluoride electrode and total ionic strength adjustment buffer. (2)
Total Organic Carbon	-	Organic material in a blended sample is oxidized and the resulting carbon dioxide is measured by infrared analysis. (2)
Total Inorganic Carbon	-	Sample is passed through a column of quartz chips wetted with 85% H_3PO_4. Temperature is held at 150°C. A release of carbon dioxide from the inorganic carbonates is measured by infrared analyses. (2)
Lead (Dissolved)	-	Determination by atomic absorption after solvent extraction. (2)
Zinc (Dissolved)	-	Determination by atomic absorption after solvent extraction. (2)
Mercury (Total)	-	Cold flame atomic absorption (automated). Determination done on a shaken sample. (2)
Mercury (Dissolved)	-	Cold flame atomic absorption (automated). (2)
Residue (Nonfilterable)	-	Sample is passed through a weighed gooch crucible with a glass fibre filter. The crucible with its contents is oven dried at 103 - 105°C. The increase in weight over that of the gooch crucible and filter represents the nonfilterable residue (suspended matter). (2)
Residue (Fixed) Non-filterable	-	The gooch crucible and glass fibre filter with its retained residue after completion of the test for residue non filterable (105°C) is ignited at 550°C for 1/2 hour. The increase in weight over that of the gooch crucible and filter represents residue fixed non filterable. (2)
Boron (Total)	-	Determined colorimetrically with dianthrimide. (3)
Aluminum (Dissolved)	-	Determination by atomic absorption - direct aspiration. (2)

Barium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Cadmium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Chromium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Cobalt (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Lithium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Molybdenium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Nickel (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Stronium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Thallium (Dissolved) - Determination by atomic absorption - direct aspiration. (2)

Definition of terms used in methods:

Dissolved Analysis (Cl, SO_4, F, etc.).

No field pretreatment. Sample was filtered through a 0.45 micron filter in the Calgary laboratory.

Total - For this program, total analysis was that analysis performed on a shaken sample.

Solvent Extraction - MIBK - APDC extraction as outlined in reference 2, pages 54 - 55.

Methods of analyses for Peace-Athabasca Delta Project. Water quality samples analysed at the temporary field laboratory located at the Peace-Athabasca Project camp in Fort Chipewyan, Alta.

pH - As described in the Calgary laboratory using a portable battery operated meter.

Conductance - As described in the Calgary laboratory using a portable battery operated meter.

Temperature - As described in the Calgary laboratory.

Dissolved Oxygen - Standard Winkler method with the azide modification. (1)

References:

1. American Public Health Association, 1965. Standard Methods for the Examination of Water and Wastewater, Twelfth Edition, New York.

2. Water Quality Division, Inland Waters Branch, Department of Fisheries and Forestry, 1971. Methods for Chemical Analysis of Waters and Wastewaters, Ottawa.

3. Levinson, A.A. (1971); an improved Dianthrimide Technique for the Determination of Boron in river waters; Water Research 5, 41-41.

The minimum detection limits and limits of accuracy of methods used by the Water Quality Laboratory at Calgary, Alberta for the Water Quality Monitoring Program and the Winter Ice Survey are as follows:

Parameter	Minimum Detection Limit	Limits of Accuracy (coefficient of variation)
Conductivity	0.2 umhos/cm	± o.5% at 520 umhos/cm
Turbidity	0.1 J.T.U.	± 9.22% at 1 JTU ± 3.96% at 10 JTU ± 1.68% at 40 JTU ± 0.45% at 100 JTU
Temperature	-	± 0.1°C in Calgary Laboratory ± 0.25°C in field
pH	-	0% at pH of 8.8 0% at pH of 4.0
Alkalinity	0.5 mg/1 Ca CO_3	± 1.48% at 33.3 mg/1 $CaCO_3$
Calcium (Dissolved)	0.05 mg/1 Ca	± 2.9% at 13 mg/1 Ca ± 0.5% at 45 mg/1 Ca
Magnesium (Dissolved)	as above as mg	as above
Hardness (Total)	as above as $CaCO_3$	± 0.65% at 52.0 mg/1 $CaCO_3$
Sodium (Dissolved)	0.1 mg/1 Na	± 0.67% at 12 mg/1 Na ± 1.29% at 67 mg/1 Na
Potassium	0.1 mg/1 Fe	± 1.09% at 6.4 mg/1 K ± 1.79% at 36 mg/1 K
Iron (Dissolved)	as above	as above

Parameter	Minimum Detection Limit	Limits of Accuracy
Manganese (Dissolved)	0.01 mg/1 Mn	as above
Copper (Dissolved)	0.001 mg/1	± 1.6% at 0.010 mg/1 Cu
Silica	0.005 mg/1	± 0.7% at 0.200 mg/1 SiO_2
Nitrate-Nitrogen (Dissolved)	0.01 mg/1 as N	± 1.6% at 0.05 mg/1 N
Total Kjeldahl Nitrogen	0.01 mg/1 as N	± 4.58% at 25 mg/1 N
Chloride (Dissolved)	0.1 mg/1 as Cl	± 0.5% at 20 mg/1 Cl
Phosphate (Ortho Dissolved)	0.010 mg/1 as PO_4	± 4.65% at 0.010 mg/1 PO_4 ± 3.98% at 0.025 mg/1 PO_4
Sulphate (Dissolved)	0.2 mg/1 as SO_4	± 3.0% at 25 mg/1 SO_4
Phosphate (Total)	0.010 mg/1 as PO_4	± 7.30% at 0.020 mg/1 PO_4 ± 4.11% at 0.050 mg/1 PO_4
Fluoride (Dissolved)	0.01 mg/1 as F	± 0.79% at 0.20 mg/1 F ± 0.93% at 1.0 mg/1 F
Total Organic Carbon	2 mg/1 as C	± 3.08% at 20 mg/1 C ± 0.02% at 30 mg/1 C
Total Inorganic Carbon	as above	similar to the above
Lead (Dissolved)	0.001 mg/1 as Pb	± 2.2% at 0.020 mg/1 Pb
Zinc (Dissolved)	0.001 mg/1 as Zn	± 1.4% at 0.010 mg/1 Zn
Mercury (Total)	0.05 ug/1 as Hg	± 5.5% at 0.3 ug/1 Hg ± 4.9% at 2.0 ug/1 Hg ± 3.3% at 8.0 ug/1 Hg
Mercury (Dissolved)	as above	similar to above
Residue (Non-filterable - 105°C)	1 mg/1	No data available
Residue (Fixed)	1 mg/1	as above
Dissolved Oxygen	0.1 mg/1 as D.O.	± 1.8% at 4.1 ug/1 D.O.
B.O.D.	0.5 mg/1 as oxygen (not based on actual analyses rather a "rule of thumb")	No data available

Parameter	Minimum Detection Limit	Limits of Accuracy
Boron	0.01 mg/I as B	No data available
Aluminum	1.0 mg/l as AL	No data available
Barium	0.1 mg/l as Ba	No data available
Cadmium	0.01 mg/l as Cd	± 3.5% at 0.01 mg/l Cd
Chromium	0.01 mg/l as Cr	± 2.9% at 0.01 mg/l Cr
Cobalt	0.01 mg/l as Co	No data available
Lithium	0.005 mg/l as Li	No data available
Molybdenium	0.05 mg/l as Mo	No data available
Nickel	0.01 mg/l as Ni	No data available
Strontium	0.02 mg/l as Sr	± 1.0% at 0.20 mg/l Sr
Thallium	0.15 mg/l as Tl	No data available

NOTE: Coefficient of variation is the ratio of the standard deviation to the arithmetic mean expressed as a percentage.

The minimum detection limits and limits of accuracy of methods used by the Water Quality Laboratory at Calgary, Alberta for the Sediment Survey are as follows:

Parameter	Minimum Detection Limit (mg/g)	Limits of Accuracy
Copper	0.01 as Cu	No data available
Lead	0.10 as Pb	" " "
Zinc	0.01 as Zn	" " "
Manganese	0.05 as Mn	" " "
Boron	0.01 as B	" " "
Calcium	0.01 as Ca	" " "
Chloride	0.1 mg as Cl	" " "

Parameter	Minimum Detection Limit (mg/g)	Limits of Accuracy
Magnesium	0.01 as Mg	No data available
Potassium	0.1 mg as K	" " "
Iron	0.05 as Fe	" " "
Sodium	0.1 mg as Na	" " "
Strontium	0.02 as Sr	" " "
Mercury	0.00005 as Hg	" " "
Lithium	0.003 as Li	" " "
Aluminum	0.10 as Al	" " "
Barium	0.05 as Ba	" " "

Lake Sediment Survey

Preliminary Treatment of Sample

The method followed for the preparation of samples for analysis is described in "Information Report NOR-X-11, Methods used for Soil, Plant, and Water Analysis at the Soils Laboratory of the Manitoba-Saskatchewan Region 1967-70", December 1971, pages 5 and 6.

Moisture contents of each air dried sediment sample was obtained by determining the weight loss at 105°C of 10 grams of sediment.

Exchangeable Analysis

A portion of the air dried sediment was taken for exchange analysis. The method followed is described in "Soil Laboratory Analysis, Alberta Soil Survey and Department of Soil Science", pages 26 and 27.

The analysis for the various exchangeable ion was performed on the leachate obtained in the method referred above.

Methods of analysis used are identical to those described under "Water Quality Monitoring Program and Winter Ice Survey" with the following exceptions:

- all results are expressed in mg/l per 100 grams of dry sediment.
- Calcium: Determination by atomic absorption direct aspiration.
- Magnesium: Determination by atomic absorption - direct aspiration.

Extractable Analysis

A suitable portion of the air dried sediment as obtained under "Preliminary Treatment of Sample" was taken and the following procedure followed:

1. 1 gram of air-dried sediment was weighed and transferred to a 250 ml erlenmeyer flask fitted with a ground glass stopper.
2. 20 mls of aqua regia (200 mls conc. HNO_3 + 600 mls conc. HCL + 200 mls demineralized water) was slowly added to each flask. Particular care was taken to minimize frothing; in addition, the flasks and contents were allowed to stand for 30 minutes to allow any frothing to subside.
3. The flasks were stoppered and the stoppers secured with masking tape.
4. The flasks and contents were shaken for five minutes on an "Eberbach" mechanical shaker set at high speed.
5. The flasks and contents were placed into a hot water bath set at $40^{o}C$ and left overnight.
6. The flasks and contents were shaken as in step 4 for 15 minutes.
7. The stopper was rinsed with three - 15 ml portions of demineralized water into the flask. Approximately 100-150 mls of demineralized water was added to each flask.
8. The contents were filtered through a number 42 Whatman filter paper in a Buchner funnel.

9. The flasks and any remaining contents were rinsed three separate times and poured through the filter paper.
10. The filtrate was transferred to a volumetric flask and bulked up to mark with demineralized water.

The contents in the volumetric flask were used for extractable analysis. The methods of analysis were identical as those described under "Water Quality Monitoring Program and Winter Ice Survey". The exceptions are the same as those noted under "Exchangeable Analysis" with the following additions.

Current methods of analysis would not permit the analysis of chloride and boron on aqua regia extracts.

DISCUSSION OF ANALYTICAL PARAMETERS

Physical

Turbidity - under natural conditions turbidity in water results from the presence of such materials as silt, clay, organic matter, phytoplankton. Excessive turbidity hinders light penetration in water and consequently reduces photosynthesis by phytoplankton and submerged vegetation.

It is a measure of the interference presented by suspended matter to the passage of light through a sample.

Color - natural color in water results from the presence of organic and inorganic colloidal materials. The sources are decaying plant materials, algae, iron and manganese. High levels of color in water have determintal effects on photosynthetic action of aquatic plants. It also limits the use of water for

drinking and recreational purposes.

Temperature - the temperature of water is important, and sometimes critical, for many uses of water. It affects the palatability of water and its suitability as a habital for aquatic life. Higher temperatures diminish the solubility of dissolved oxygen in water; increases the metabolism, respiration, and oxygen demand of fish and other aquatic life; intensifies the toxicity of many substances; and increases the solubility of chemical compounds present as colloidal and suspended materials.

Specific Conductance - it is a measure of the water's ability to conduct an electric current, therefore, is dependent upon the ion concentration in the water and the temperature of the water. A rough estimate of the total dissolved salts in a water can be calculated by multiplying the conductance value by 0.6.

All salts in water change the physical and chemical nature of the water and exert osmotic pressure. Some salts have physiological or toxic effects as well. Waters continuing more than 4,000 mg/l of total salts are generally considered unfit for human use. Total salt concentrations in water greater than 3,000 mg/l are generally injurious to most plants. Wildlife may be injured by drinking water that contains more than 7,000 mg/l total salts. Continous use of such water by wildlife may cause general loss of condition, weakness, scouring, unthriftiness, bone degeneration, and death. Any water with an osmotic pressure of greater than six atmospheres, about 7,000 mg/l as sodium chloride, may be expected to be deleterious to fresh water fish. Dissolved salts in water may also influence the toxicity of heavy metal and

organic compounds to fish and other aquatic life.

Major Ions

Alkalinity - the alkalinity in natural waters is caused by the presence of carbonates, bicarbonates, hydroxides, and to a lesser extent by borates, silicates, phosphates, and organic substances. Alkalinity is not considered to be deterimental to humans and wildlife, although at a total alkalinity of 170 mg/l animals have been reported to develop diarrhea. Fish and other aquatic life and plants do not seem to be affected by alkalinity.

Calcium - calcium salts and ions are among the most commonly encountered substances in water. Calcium may result from the solution of calcium bearing minerals, leaching of soil and other natural sources. Cation-exchange equilibra have a considerable influence on calcium concentrations in most natural waters. The suspended sediments of river water can also provide a reservoir of calcium ions.

Calcium is an essential element for animal and plant growth. Canadian Drinking Water Objectives, 1968 recommend that 75 mg/l is an objective level and 200 mg/l is an acceptable level for calcium. Calcium has also been shown to reduce the toxicity of many chemical compounds to fish and other aquatic fauna.

Carbon - the forms in which carbon are present in natural waters ordinarily lie between 0.4 and 1.0 mg/l. The natural establishment of equilibria to restore the free CO_2 in water, removed by aquatic growth, from natural inorganic sources is a slow process and probably never exceeds 1 mg/l.

On the other hand, the CO_2 supplies from the breakdown of organic matter by aerobic bacteria in natural water can be massive.

Carbon present in natural water as carbonates, bicarbonates, and organic matter are not considered as harmful to animals and plants. However, carbon as CO_2 in natural waters in concentrations of 1.0 to 6.0 mg/l will cause fish to avoid such waters. It has been reported that free CO_2 in excess of 20 mg/l may be harmful to fish in normal fresh water, but when the dissolved-oxygen content drops to 3 to 5 mg/l, lower CO_2 concentrations may be detrimental.

Chlorides - chlorides are present in practically all natural waters, mostly the concentrations are low. Exceptions occur where streams receive inflows of high-chloride groundwater.

Chlorides are generally not harmful to humans until high concentrations are reached, although they may be injurious to people suffering from heart and kidney diseases. Restrictions on chloride concentrations in drinking water are generally based on palatability requirements rather than on health. The Canadian Drinking Water Objectives of 1968 recommends that chlorides do not exceed 250 mg/l.

Chlorides are essential to plant growth, but in quantities greater than 200 mg/l they are considered harmful to most plants. In general, chlorides are twice as toxic to plants as sulfates.

Chloride concentrations in excess of 4,000 mg/l have been reported to cause injury to wildlife for watering purposes.

The following concentrations of chloride have been reported to be harmful to fish:

Trout	400 mg/l
Coarse Fish	2,000 mg/l
Bass, pike, perch	4,000 mg/l

Chlorinity is closely related to total salinity and its effects on osmosis: hence it is evident that fresh-water fish cannot tolerate excessive changes in salinity.

Magnesium - the magnesium concentration in most natural fresh waters is much lower than the calcium concentration. It combines with calcium to form the bulk of the hardness in water.

Magnesium is an essential element for humans and is considered relatively non-toxic to man because, before toxic concentrations are reached in water, the taste becomes quite unpleasant. At high concentrations, magnesium salts have a laxative effect on humans. The 1968 Canadian Drinking Water Objectives recommends a limit of 150 mg/l.

Magnesium is essential to normal plant growth. It has been reported that magnesium in water in concentrations up to 24 mg/l will probably not effect seriously the growth of woody plants.

Animals also require magnesium salts in their diet but high concentrations in drinking water may cause scouring disease. Threshold limits of 500 mg/l in drinking water has been suggested for wildlife by a number of workers. Ingestion of mixtures of sodium salts and magnesium and nitrate ions have caused poisoning among ducks.

Magnesium salts in certain combinations can be toxic to fish. Magnesium chloride and nitrate was found to be toxic at concentrations between 100 and 400 mg/l as magnesium. Whereas, magnesium chloride, nitrate and sulfate, at concentrations between 1,000 and 3,000 mg/l as magnesium have been tolerated for 2-11 days.

Nitrogen - nitrogen occurs abundantly in nature. It is an essential constituent of protein in all living organisms and it is present in many mineral deposits as nitrates. In organic matter it undergoes changes of decomposition from complex protein through amino acids to ammonia, nitrites, and nitrates. This cycle in nature is dependent upon bacterial action for decomposition and upon photosynthesis for reconstitution of organic matter. In natural waters, nitrogen may be present in many forms, but the ones that are commonly measured are ammonia, organic nitrogen, nitrites, and nitrates.

In water suitable for most beneficial uses, the total concentration of nitrogen compounds should be less than 10 mg/l. Nitrogen in the form of nitrate is a major nutrient for plant growth. It is seldom deleterious to plants in any form. However, the total concentration of nitrogen is not as important as the form in which it exists for fish-food organisms. Organic nitrogen, amino acids, and ammonia may inhibit biological growth whereas nitrates stimulate it. Fish production has shown to be highest in lakes and streams containing the most organic nitrogen.

Oxygen, Dissolved - the content of dissolved oxygen in natural waters at equilibrium with a normal atmosphere is a function of the temperature and the salinity of the water. The ability of water to hold oxygen decreases

with increases in temperature or dissolved solids. Natural waters are seldom at equilibrium and seldom saturated with dissolved oxygen, for temperatures are changing and physical, chemical, bio-chemical, or biological activities are utilizing or liberating oxygen.

The presence of dissolved oxygen in natural waters is seldom considered to be deleterious to humans and animals, for it has no adverse physical effects when ingested, and it actually increased the palatability of the water.

No general statement can be made to give the minimum dissolved-oxygen concentration required to support fish life, owing to the fact that the oxygen requirements for fish vary with the species and age of the fish, with prior acclimatization, with temperature, with the concentration of other substances in the water, and with several other factors.

pH (Hydrogen Ion Activity) - the hydrogen ion activity in a natural water is related intimately to the concentration of many other substances, particularly the weakly dissociated acids and bases. In surface or ground waters it may be attributable to natural causes, such as humic acids extracted from swamps or peat bogs, or to industrial wastes or acid-mine drainage.

The activity of the hydrogen ion can be most conveniently expressed in logarithmic units, and the abbreviation "pH" represents the negative base - 10 log of the hydrogen-ion activity in moles per liter. Thus, if (H+) = 10^{-15} moles per liter, then the pH = 5.

An excessive concentration of hydrogen ions can adversely affect water for one or more beneficial uses. For most uses pH values between 6 and 9 are considered acceptable.

pH values of most inland waters containing fish range between 6.7 and 8.6 and most workers have concluded that direct lethal effects of pH are not produced within a range of 5 to 9.5, but from the standpoint of productivity it is best to maintain the pH in the range of about 6.5 to 8.2.

Phosphorus - the form in which phosphorus is likely to be present in natural waters is somewhat uncertain, but the most probable forms are phosphate anions, complex phosphate compounds, complexes with metal ions, and colloidal particulate material.

Phosphorus may occur in surface or ground waters as a result of leaching from minerals or ores in natural process of degradation or from agricultural drainage, as one of the stabilized products of decomposition of organic matter, and as a major element of municipal sewage. In surface waters, however, phosphorus is seldom found in significant concentrations because it is utilized by plants.

Phosphorus is a major plant nutrient and the element is essential to all life forms. It does not appear to have any physiological significance to life forms in relatively high concentrations.

Phosphorus seldom exhibit toxic effects upon fish and other aquatic life and may be beneficial to fish culture by increasing the food supply.

The discharge of excessive amounts of phosphates to streams and lakes may result in an overabundant growth of algae with concomitant odors and detrimental to fish.

Potassium - potassium is present in nearly all natural waters but the rather narrow range of concentrations observed suggests a significant chemical control mechanism may be involved. The nature of this mechanism, however, is not well known.

Potassium is an essential nutritional element for plant and animal growth. In excessive quantities it is toxic to plants and cathartic to humans. The extreme limit of potassium concentration permissible in drinking water is considered to be 1,000 mg/l. For good plant development it must be maintained in proper balance with other mineral requirements, such as phosphorus. The effects of excess potassium on wildlife are not clearly understood.

The toxicity of potassium to fish and other aquatic life is reduced by calcium and to a lesser degree by sodium. Potassium can be toxic to fish in soft water at concentrations of 50-200 mg/l. In a range of harder waters the concentrations found to be toxic to fish were about 400 mg/l.

Silica - silica occurs in natural waters as finely divided or colloidal suspended matter, in concentrations of 1-40 mg/l.

In concentrations found in natural water, silica appear to have no adverse physiological effect to humans and animals. Plants require silica in

concentrations above 0.5 mg/l for growth. An abundance of silica in water, along with other necessary nutrients, favors the growth of diatoms.

Sodium - sodium is present in natural waters as the sodium ion and as compounds of sodium. Most sodium salts are extremely soluble in water, thus any sodium that is leached from soil or discharged to streams will remain in solution.

Sodium in drinking water at concentrations of 200 mg/l may be injurious to humans, especially to persons suffering from cardiac, renal, and circulatory diseases. Concentrations of various sodium salts in drinking water may also be deleterious to various animals above 2,000 mg/l.

Several investigators have reported that 500-1,00 mg/l of sodium was toxic to fish in soft waters. However, in waters supporting a good fish fauna in the United States, the concentration of sodium plus potassium was less than 85 mg/l.

Sulfates - sulfates occur naturally in waters mostly as the sulfate ion as a result of leaching from gypsum and other common minerals. The sulfate ion has a tendency to form ion pairs and complexes with many metal ions and is involved in biological processes.

The 1968 Canadian Drinking Water Objectives recommend acceptable limits of sulphate as 250 mg/l. Waters with sulfate concentrations of greater than 500 mg/l may cause gastrointestinal irritation and catharsis, and usually has an objectionable taste.

Wildlife drinking water containing 2,000 to 3,600 mg/l of sulfate has been reported to develop run-down, ragged appearances and eventually weaken and die.

Waters supporting good game fish have been reported to contain less than 90 mg/l sulfates.

Trace Elements

Aluminum - aluminum is not likely to occur in surface water in excessive quantities for long because it precipitates and settles or is absorbed as aluminum hydroxide, aluminum carbonate, etc. In streams, the presence of aluminum ions may result from industrial wastes or more likely from waste-treatment plants.

No evidence has ever been found to prove that the use of aluminum in water supplies, or in cooking utensils and materials is harmful to human beings. Much higher levels of aluminum than those found in food or water have been fed continuously to animals without observable harm. However, in excessive amounts, there is the risk that aluminum will interfere with phosphorus metabolism.

Aluminum has been reported to be harmful to many plants in concentrations between 1 and 14 mg/l.

Aluminum concentrations in the range of 0.07 - 5.0 mg/l have been reported lethal to fish and aquatic animals in time periods between 5 minutes and one week.

Barium - barium is not normally present in natural surface or groundwaters in measurable quantities because the barium ions discharged to natural water are quickly precipitated as sulfates and carbonates and removed by absorption or sedimentation.

The 1968 Canadian Drinking Water Objectives prescribes a maximum permissible limit of 1.0 mg/l. Fatal oral doses of barium for man is reported to be 550 - 600 mg/l.

Barium is not utilized by most plants except in trace quantities. It is considered to be poisonous to most plants.

Concentrations of barium greater than 5 mg/l have been reported to be harmful to many fish species.

Boron - boron occurs in natural waters as sodium borate or as calcium borate. It enters natural waters through dissolution of boron containing mineral deposits, or fossil fuels, or industry. Boric acid is used as a bactericide and fungicide.

The 1968 Canadian Drinking Water Objectives recommends 5.0 mg/l as the maximum permissible limit for humans. Fatal doses for adults have been reported between 5 and 45 grams.

Lethal doses of boron for animals have been reported to vary from 1.2 to 3.45 grams per Kg of body weight, according to the species.

Boron is an essential element in the nutrition of higher plants, yet concentrations of boron in waters in excess of 0.5 mg/l may be deleterious.

Fish and aquatic life are not affected by boron concentrations in water less than 5,000 mg/l.

Cadmium - cadmium occurs in natural waters as the salts of chlorides, nitrates, sulfates. Cadmium carbonates and hydroxides are insoluble in water and, hence will be precipitated at high pH values. Cadmium salts enter natural water in wastes from electroplating plants, pigment works, textile printing, lead mines, and chemical industries.

Oral ingestion of cadmium has been reported as the cause of a number of human deaths. It tends to concentrate in the liver, kidneys, pancreas, and thyroid of humans and animals and once it enters the body, it is likely to remain. Human beings have been sickened by as little as 14.5 mg. of cadmium. The 1968 Canadian Drinking Water Objectives recommends the maximum permissible limit for cadmium as 0.01 mg/l.

Fatal doses of cadmium have been reported for animals to be 0.15 to 0.6 grams per Kg of body weight and it has been suggested by a number of workers that the concentration of cadmium in drinking water for animals should not exceed 0.10 mg/l and preferably lower.

Cadmium concentrations of 28 mg/l in water have been reported to be injurious to many plant species.

The lethal concentration of cadmium for fish varies from about 0.01 to about 10 mg/l depending on the species, the type of water, temperature, and time of exposure.

Chromium - chromium is present in natural waters as divalent, trivalent, and hexavalent salts. All of the dichromates are quite soluble in water. Of the trivalent chromic salts, the chloride, nitrate and sulfate are readily soluble in water, but the hydroxide and carbonate are quite insoluble. Of the hexavalent chromate salts, only sodium, potassium, and ammonium chromates are soluble.

Chromium compounds find their way into natural waters mainly in wastes from industries. The hexavalent chromium salts being the most extensively used in the manufacturing processes.

There is no evidence that chromium salts are essential or beneficial to human and animal nutrition. Chromium salts are not retained in the body but are rapidly and completely eliminated. The toxic dose for man is reported to be about 0.5 grams. The 1968 Canadian Drinking Water Objectives recommends a maximum permissible limit of 0.05 mg/l as hexavalent chromium.

The reported evidence on toxic doses of chromium for animals is voluminous and varied but a summary of the evidence appears that concentrations of chromium, trivalent or hexavalent, of 5.0 mg/l will not interfere with the beneficial use of water for wildlife watering.

Chromium is present in trace amounts in plants, but there is evidence that chromium is essential or beneficial for plant nutrition. According to a number of workers chromium is toxic to plants at all concentrations, either directly or by concentrating the intensity of injury caused by other metals.

The toxicity of chromium salts toward aquatic life varies widely with the species, temperature, pH, valence of the chromium, and hardness of the water. A chromium concentration, trivalent or hexavalent, of 1.0 mg/l is considered safe for most fish species but a concentration of 0.05 mg/l appears to be the safe limit for other aquatic life.

Cobalt - cobalt as the cobaltous ions are relatively stable in natural water. The cobaltic ions are powerful oxidizing agents and consequently are unstable in natural waters. Cobalt finds its way in natural waters mostly from the wastes of industries.

It has been reported that cobalt has a relatively low toxicity to man, and that traces of cobalt are essential to nutrition. A maximum safe con-concentration of cobalt in drinking water cannot be established or estimated on the basis of present knowledge.

Animals vary in their ability to tolerate cobalt but trace amounts of cobalt appear to be essential in their diet. The minimum daily requirement for growing animals is reported to be 0.1 mg. The daily intake of a small amount of cobalt is reported to produce a striking increase in the number of circulating red blood cells in a number of different species of animals.

There also appears to be a relationship between the beneficial and detrimental effects of cobalt in the diet and the content of vitamin V_{12}.

Trace amounts of cobaltous ion appear to simulate the growth of fish and other aquatic organisms. Cobalt concentrations of 1.0 mg/l have been reported as not harmful to many species of one-year-old fish or to the insect larvae forming the food for these fish. At higher concentrations, however, cobalt ions have demonstrated pronounced toxic effects.

Copper - copper salts occur in natural surface waters only in trace amounts, up to about 0.05 mg/l, so that their presence is generally the result of pollution.

The chloride, nitrate, and sulfate of divalent copper are highly soluble in water, but the carbonate, hydroxide, oxide, and sulfide are not. The cupric ion, therefore, introduced into natural waters at pH 7 or above will quickly precipitate as the hydroxide or as basic copper carbonate to be removed by adsorption and/or sedimentation.

Copper is found in traces in all plant and animal life, and it is believed to be essential for nutrition. The physiological function of copper appears to be involved in the metabolism of iron. It is not considered to be a systemic poison as most of the copper ingested is excreted by the body and very little is retained. There is no evidence that poisoning has ever occurred as a result of consumption of copper in water.

The limiting factor for copper in drinking water is taste. Threshold concentrations for taste are in the range of 1.0 - 2.0 mg/l of copper, while as much as 5 - 7 mg/l makes the water completely undrinkable. The 1968 Canadian Drinking Water Objectives recommends acceptable limits of 1.0 mg/l.

Small amounts of copper are beneficial for hemoglobin count and growth in animals but concentration of one gram per pound of live weight have been reported to be toxic for most animals.

Minute quantities of copper are beneficial or essential for plant growth. However, copper concentrations of greater than 0.1 mg/l are injurious to many plants and toxicity symptoms develop at concentration in the range 0.5 - 1.5 mg/l for most plants.

The toxicity of copper to aquatic organism varies significantly not only with the species, but also with the physical and chemical characteristics of the water, such as its temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts is reduced by the precipitation of copper carbonate and other insoluble compounds. Synergism exists between the sulfates of copper and zinc, and copper and cadmium in their toxic effect on fish. It also exists between copper and mercury. Copper concentrations as low as 0.01 to 0.5 mg/l have interfered with the self-purification processes of streams by killing the stream bacteria.

On the basis of reported information on copper toxicity to fish and other aquatic life, concentrations of less than 0.02 mg/l copper in waters appear not to be deleterious.

Fluorides - fluorides are not commonly found in high concentrations in natural surface waters, but they may occur in detrimental concentrations in ground waters.

Fluorides in quantitites greater than 0.5 gms per Kg of body weight are generally fatal to humans. However, abundant literature is available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay.

The 1968 Canadian Drinking Water Objectives recommends that the concentration should not exceed 1.5 mg/l.

Fluorides in waters appear to have no effect on plants in concentrations less than 10 mg/l.

The effects of fluorine in drinking water for animals is analogous to those for humans. Reported effects in the literature indicate that 1.0 mg/l of fluorine appears to be the threshold value below which no harm results to most animals.

Fluoride ions appear to have direct toxic properties toward aquatic life, and in addition there seems to be a relationship between fluorides in water and the condition of the teeth of the fish. Reported effects of fluorides

on fish indicate that 1.5 mg/l appears to be the value below which no harm results from its presence in water.

Iron - iron is present in well-aerated natural surface waters generally as the ferric ion. Although many of the ferric and ferrous salts are highly soluble in water, the ferrous ions are readily oxidized in natural surface waters to the ferric condition and form insoluble hydroxides. These precipitates tend to agglomerate, flocculate, and settle or be absorbed on surfaces; hence, the concentration of iron in well-aerated waters is seldom high. In ground water, however, the phH may be such that high concentrations of iron remain in solution.

Iron in trace amounts is essential for nutrition. The daily nutritional requirement is 1 to 2 mg per day, and most diets contain an average of 16 mg per day. The taste threshold of iron in water is about 0.1 mg/l. The 1968 Canadian Drinking Water Objectives recommends an objective limit of 0.05 mg/l based on taste considerations and an acceptable limit of 0.3 mg/l based on considerations of effects on household uses.

Iron is an essential constituent of animal diets, but animals are sensitive to change in iron concentrations and may not drink water high in iron.

Iron in water is of little practical significance to plant growth.

The effects of iron on fish and other aquatic life are varied. However, it is the opinion of most researchers that much of the killing action is due to coatings of iron oxide or hydroxide on the gills which causes

an irritation and blocking of the respiratory channels. It is generally accepted that waters supporting good fish fauna have iron concentration less than 0.7 mg/l.

Lead - lead concentrations in natural waters range from traces to 0.04 mg/l. It may be introduced into natural waters as a constituent of various industrial and mining effluents, or as a result of the action of water on lead in pipes.

Certain lead salts, such as acetate and chloride, are readily soluble, but owing to the fact that the carbonate and hydroxide are insoluble and the sulfate only sparingly soluble, lead will not remain long in natural waters.

Foreign to the human body, lead is a cumulative poison. It tends to be deposited in bone as a cumulative poison. The mean daily intake of lead by adults in North America is about 0.33 mg. Of this quantity, 0.01 to 0.03 mg per day are derived from water used for cooking and drinking. Lead poisoning among human beings is reported to have been caused by the drinking of water containing lead in concentrations varying from 0.042 mg/l to 1.0 mg/l. The 1968 Canadian Drinking Water Objectives recommends the maximum permissible limit for lead as 0.05 mg/l.

Lead is not among the metals considered essential to the nutrition of animals. Most authorities agree that 0.5 mg/l of lead is the maximum safe limit for lead in a potable supply for animals.

It has been stated by workers in plant nutrition that lead is harmful to plants at all concentrations. However, further investigations in this field are needed.

A review of the literature on the toxicity of lead for fish and other aquatic life indicates that: lead is more toxic in soft water than in hard water; the toxicity increases with a reduction of the dissolved oxygen concentration of water; in water containing lead salts, a film coagulated mucus forms, first over the gills and then over the whole body of the fish, probably as a result of a reaction between lead and an organic constituent of mucus, causing death by suffocation; and lead concentrations as low as 0.1 mg/l have been deleterious to fishlife, especially in soft waters.

Lithium - the data for major rivers of North America show median values in the range 0.001 - 0.002 mg/l. Lithium is not widely distributed in nature, but when brought into solution by weathering reactions, it generally remains in the dissolved state.

Lithium is present in potable waters in concentrations below which it is considered harmful to human beings and animals.

Lithium is potentially toxic to plants. In soil moisutre, 1 to 4 mg/l of lithium, as lithium chloride, caused symptoms of lithium toxicity.

Lithium is lethal to fish only in high concentrations, but dilute concentrations of lithium chloride were shown to be deleterious to the eggs of various organisms, by retarding their development.

Manganese - manganese occurs in natural waters in the divalent and trivalent form. The chlorides, nitrates, and sulfates are highly soluble in water; but the oxides, carbonates, and hydroxides are only sparingly soluble. For this reason, manganic or managanous ions are seldom present in natural surface waters in concentrations above 1.0 mg/l. In ground water or lakes subject to reducing conditions, manganese can be leached from soils and sediments and occur in high concentrations.

Manganese is essential for the nutrition of human beings and animals. A deficiency of manganese results in impaired or abnormal growth, disturbance of the control nervous system, and possibly interference with reproductive functions. In concentrations not causing unpleasant tastes, manganese is regarded by most investigators to be of no toxicological significance in drinking water. The 1968 Canadian Drinking Water Objectives recommend the acceptable limit as 0.05 mg/l for aesthetic reasons.

Manganese is essential for plant metabolism. It has been shown that trees and aquatic plants are accumulators of manganese, especially in the reproductive parts of the plants. When these plant parts die back, or are shed, the manganese becomes available for solution in run-off and soil moisture. Concentrations of manganese up to 0.50 mg/l in water are considered not to be harmful to plant growth.

The toxicity of manganese towards fish is dependent upon many factors, but generally, manganese in concentrations less than 1.0 mg/l is not considered to be harmful to fish and other aquatic life species.

Mercury - the natural distribution of mercury in water results from the contact of water with soil and rock. It has the tendency to sorb readily on earth material and it is because of this tendency that suspended matter in natural waters may contain from 5 to 25 times as much mercury as the water around it. It is for this reason that mercury from natural sources occurs in natural water, generally, in concentrations less than 0.0001 mg/l. Mercury may also be introduced into natural waters as synthetic organic and inorganic salts that are used commerically and industrially.

The tendency of mercury to sink rapidly and combine with sulphite in anaerobic bottom sediments to form cinnabar appears to be the major scavenging mechanism. Another mechanism which keeps the content of soluble mercury low is the relatively high reactivity of mercury with organic substances and the resulting uptake by living and non-living organic matter.

Mercury is not known to be essential for plant and animal metabolism. However, it tends to concentrate in living tissue once it has been assimilated, and there is evidence that the extent of concentration increases with each step up the food chain, from plankton to fish to man. Organisms tend to purge themselves of mercury once the supply is cut off, but the efficiency of recovery varies from organ to organ and organism to organism.

Mercury, mercury salts, and mercury compounds are considered to be highly toxic to human beings and animals, and fatal doses vary from 3 to 30 gms. The 1968 Canadian Drinking Water Objectives do not include limits for mercury but the Prairie Provinces Water Quality Objectives for surface waters recommends a limit of 0.0001 mg/l for all uses.

Terrestrial plants absorb mercury as well as other minor elements, but there seems to be little tendency for these plants to concentrate mercury above environmental levels. Toxicity of mercury to terrestrial plants apparently depends more on the chemical state of the element than on its concentration.

Mercury ions are considered to be highly toxic to aquatic life. For fresh water fish, concentrations of 0.004 to 0.02 mg/l on mercury have been reported harmful.

Molybdenum - molybdenum is a rather rare element, but its presence in surface and groundwaters is of importance because it is accumulated by vegetation to the extent that it can become toxic to grazing animals and wildfowl. The median concentrations of molybdenum in North American Rivers have been quoted at .0003 mg/l.

The element molybdenum is known to be essential in plant and in animal nutrition, but it is required only in very small quantities. Quantities of molybdenum in the range 0.1 - 125 mg have been shown to be toxic to animals depending on the size of the animal and the compounds of molybdenum used in the test. Molybdenum trioxide, calcium molybdate, and ammonium molybdate were shown to be the most toxic to animals and wildfowl. Concentrations of molybdenum in the range 0.5 - 200 mg/l have been reported to be injurious to plants.

The toxicity of molybdenum to fish and other aquatic life is dependent mostly on the hardness of the water and the size and species of the aquatic

organism.

Nickel - nickel occurs in natural waters as the nickel ions and as nickel salts of nitrate, sulfate, ammonium sulfate, and chloride. Nickel may also enter surface or ground waters in the effluents from metal-plating works.

Data on the toxicity of nickel to man is almost non-existent, but the toxicity is believed to be very low. Poisoning of human beings by nickel or nickel salts is almost unknown.

The effects of nickel salts upon the growth of plants has been reported to be very injurious no matter how small the quantity.

Nickel in the water supply of amphibia, reptiles, birds, mammals and animals has been demonstrated to hinder the growth of the liver.

Nickel appears to be less toxic to fish and other aquatic organisms than copper, zinc, brass, and iron, as reported by many researchers. Nickel combines readily with cyanide to form a nickel-cyanide that is relatively stable in moderate alkaline water. In acid waters, however, the complex breaks down and releases hydrogen cyanide which is highly toxic to aquatic organisms.

Strontium - strontium occurs in nature as the salts of carbonate and sulfate. As both of these salts are relatively insoluble in water, strontium ions are not likely to occur in high concentrations in surface waters. Strontium is not absorbed readily by soils, hence it may be expected to

travel readily along with ground waters. Strontium may also enter surface water from the wastes of sugar beet refineries and from manufacturing processes.

Strontium is present in plant and animal tissue in trace quantities, but it occurs in much higher concentrations in bone structures. There is no evidence that strontium is essential for plant nutrition, but there are indications that it is necessary for the growth of animals and especially for calcification of bones and teeth.

Toxicologically, no evidence could be found to show that non-radioactive strontium salts taken orally by man or animals produces deleterious action.

Radioactive strontium (Sr-90), owing to its long half-life and its tendency to accumulate in bone structure, rates second in radioactive materials as a hazard to human health. The 1968 Canadian Drinking Water Objectives recommends as an objective less than 10 picocuries per litre for radioactivity in water supplies.

Plants tend to accumulate radiostrontium from soils and water contaminated with fallout from nuclear explosions or waste products from nuclear reactors. The reported uptake of radiostrontium by aquatic plants showed concentration factors in the order of 100 to 800 for hard and soft water, respectively.

For fish, it was observed that radiostrontium concentrated in the flesh, bones, and scales by factors of 2.6, 71, and 209, respectively. Fish in a lake that received radioactive waste effluents concentrated radiostrontium

by factors of 20,000 to 30,000 in hard tissues.

Thus, it is evident that the major hazard to humans and animals of radiostrontium in water lies not in direct consumption but in plants and fish that accumulate this element.

Thallium - thallium salts, for the most part, are highly soluble in water and consequently natural dissolution and any industrial discharges of this element are not likely to form precipitates with the anions present in waters.

Thallium is a cumulative poison, four times as toxic as arsenious oxide, and it affects the sympathetic nervous system, causes muscular pains, endocrine disturbances, and loss of hair. It does not occur normally in animal tissues, but when taken into animal bodies it is cumulative. Doses of 10 to 40 mg/kg as thallium was lethal to most animals and birds.

Zinc - zinc is abundant in nature in a form that is sparingly soluble in water. Consequently zinc is present in most natural waters in trace amounts only. The carbonate, oxide, and sulfide salts of zinc are very insoluble in water, thus it is to be expected that some zinc will be precipitated and be removed readily in most natural waters. Further, there is some evidence that zinc ions are adsorbed strongly and permanently on silt, with a result inactivation of the zinc.

Zinc also enters natural water systems in wastes from manufacturing processes, mining areas, metal-plating works, and small-arms ammunition

plants.

Zinc has no known adverse physiological effects upon man and animal except at very high concentrations. The 1968 Canadian Drinking Water Objectives recommends an acceptable limit for zinc at 5.0 mg/l mostly because the taste threshold for zinc occurs at about 5.0 mg/l.

Zinc in small amounts is considered essential for plant nutrition, but toxicity results when concentrations exceed a very low level.

It is towards fish and aquatic organisms that zinc exhibits its greatest toxicity. The sensitivity of fish to zinc varies with species, age, and condition, as well as with the physical and chemical characteristics of the water. Concentrations of zinc as low as 0.1 mg/l in soft water have been reported to be lethal, but calcium is antagonistic toward such toxicity. The addition of 1 mg/l of calcium to soft water increased the lethal limit of mature fish to 0.3 mg/l zinc and in water with 50 mg/l of calcium, as much as 2.0 mg/l of zinc was not toxic.

ANALYTICAL RESULTS AND DISCUSSIONS

Water Quality Monitoring Program

General

This program was initiated in April, 1971 and concluded in June, 1972. Due to severe winter conditions in 1971 and again in 1972, and to difficulties in obtaining transportation to collect the samples at proposed frequencies, the water quality data presented for this program has gaps which make interpretation difficult and in some cases impossible. In addition, flow data for a number of the sampling locations was not collected. Thus, interpretation of the results of this program was limited to those lake systems or parts of lake systems where flow data was available.

The locations of the sampling sites for this program are shown in Figure 2, and the analytical data for these sampling locations are presented in Appendix A, Tables I and II.

Lake Claire - Lake Mamawi Basin

General Considerations

The Lake Claire - Lake Mamawi Basin can be classed as a shallow water open-basin fed by two small streams, Birch and McIvor, with a small outlet stream, Prairie, inflowing to Mamawi Lake. The outflow from Mamawi Lake is mainly to the east of the Chenal des Quatre Fourches and/or to the west end of Lake Athabasca and consequently to the Riviere des Rochers. However, on a much less frequent basis.

Because of this shallow water in this basin and the thickness of the ice formed during the severe winter months, averaging four feet, the amount of water in this basin during the winter period was restricted to shallow pools. Consequently sampling for water quality was severely restricted and very little data for this period is available for presentation.

Quality Considerations

The average chemical composition as weighted averages for dissolved solids, and for the chemical parameters of this basin on a high, intermediate, and low discharge or volume basis was presented in Table IV.

For the inflowing streams, the Birch and McIvor, the results show that during periods of intermediate discharge the Birch River carried more total dissolved solids per unit volume than during periods of high discharge, whereas the reverse is true of the McIvor River, it carries more total dissolved solids per unit volume during periods of high discharge. In addition, the results show that the McIvor River carried a high discharge weighted average of total dissolved solids per unit volume than the Birch River. The McIvor River is also shown to carry more sodium, calcium, silica, and sulfate ions per unit volume than the Birch River.

During periods of intermediate discharge the waters of the Birch River are characterized by increased contents of sodium, bicarbonates, sulfates, and chlorides, and during high discharge periods by increased contents of calcium. The increase in sodium, sulfates and chlorides demonstrates the relative importance of groundwater inflow in this river during intermediate discharge period, while the increase in calcium shows the importance of surface runoff

from high calcium soils during the high discharge period.

The McIvor waters are characterized by increased contents of sodium, calcium, magnesium, sulfates, and chlorides during the high discharge periods. The increase in these elements during the high groundwater period demonstrates the importance of the hydraulic head in this area causing the increased surface waters to penetrate to bedrock and subsequently increasing the discharge of high salinity water from depth as seepage and/or as springs.

The chemical composition of the waters of Lake Claire is governed by the chemical composition of its inflowing streams and by the detention period of the waters in the lake.

The weighted averages for total dissolved solids of Lake Claire waters show that during periods of low discharge the total dissolved solids content per unit volume of the waters of the lake increases approximately nine fold over the intermediate discharge period. This significant increase in total dissolved solids per unit volume is due to: (1) concentration of the dissolved solids by ice forming processes, and (2) release of elements from the lake bottom deposits under reducing conditions which occur during winter periods.

The weighted average results also show higher total dissolved solids content per unit volume during the period of intermediate discharge than during the period of high discharge. This difference is considered to be brought about by dilution during the high discharge period.

Further, a comparison of the weighted average results for total dissolved

solids per unit volume for the inflowing streams and Lake Claire show that a concentration of dissolved solids per unit volume is occurring in the lake (301.4 to 434.8 mg/l for the intermediate discharge period). The magnitude of this increase in total dissolved solids content in the lake waters can only be determined by a continuing water quality monitoring program.

The weighted average results for the Lake Claire Basin show that during periods of intermediate discharge the waters of Lake Claire are characterized by increased contents of sodium, calcium, magnesium, potassium, bicarbonates, sulfates, and chlorides over the contents of these ions being discharged to the lake in the waters of the Birch and McIvor Rivers.

For the outflowing stream, the Prairie, the results show that during periods of high discharge this river carries slightly more total dissolved solids per unit volume than during the periods of intermediate discharge. During the periods of high discharge the waters of this river are characterized by increased contents of sodium, magnesium, sulfates, and chlorides, and during intermediate discharge periods by increased contents of calcium, and bicarbonates. There is relatively no flow in this river during the low discharge period, November to March.

The weighted average results for Lake Mamawi show that during periods of high discharge the waters of this lake contain higher total dissolved solids than during periods of intermediate discharge. This lake is frozen throughout during the winter periods and this higher concentration of total dissolved solids during the period April-June is considered to be the result of the ice-melt in the lake as the discharge from Lake Claire, through the Prairie

River, does not reach its maximum until July or later.

The chemical composition of the waters of Chenal des Quatre Fourches (Appexdix A Table I) for the month of June show that the concentrations of the major ions are similar to the concentration of the major ions in the waters of Lake Mamawi indicating this river carries the major portion of the discharge waters from Lake Mamawi.

Of the total trace metal results presented for this basin (Appendix A Table I), boron is the only trace metal in significant quantities being discharged to the lakes. However, the concentrations of many of the trace metals analysed for in this program increase very significantly during the winter period in the waters of Lake Claire, as discussed under the Water Quality Ice Cover Survey section of this report.

The water quality results presented in this report, in general, show that relatively high concentrations of sodium, calcium, magnesium, chlorides, and sulfates are being discharged to this basin and that these ions are being concentrated in the lake waters. The significance of this concentration can only be determined by a continuing water quality monitoring program.

The importance of a continuing water quality monitoring program, particularly in the Lake Claire - Lake Mamawi Basin, can only be assessed from the scanty information gathered during the 15 month period of this study, but the information to date, both quality and quantity, indicate that close scrutiny of the quality of the waters in this basin should be maintained for salts build-up with subsequent damage to the delta's eco-system. The importance

TABLE IV

LAKE CLAIRE - LAKE MAMAWI BASIN

COMPOSITION OF BIRCH RIVER

Parameters	Annual Discharge-Weighted Average (mg/1)	Discharge-weighted average (mg/1) (high discharge) April-June	Discharge-weighted average (mg/1) (intermediate discharge) July-Oct.	Discharge-weighted average (mg/1) (low discharge) Nov.-March
Na	36.9	29.9	54.6	175.0
K	2.04	2.2	1.6	3.2
Ca	23.9	26.5	16.6	77.3
Mg	11.4	7.1	7.1	23.0
Al	-	-	-	-
SiO_2	3.7	3.4	4.8	9.8
HCO_3	65.4	63.3	69.8	297.4
SO_4	49.1	49.8	53.8	120.0
Cl	47.8	38.0	77.4	260.0
F	-	0.10	0.13	-
NO_3	0.02	0.01	0.04	0.09
Total	240.26	220.31	285.87	965.79
Average Monthly Discharge	8.799×10^3 c.f.s.			
Number of analyses	7	3	4	1

TABLE IV (cont'd)

COMPOSITION OF MCIVOR RIVER

Parameters	Annual Discharge-Weighted-Average (mg/l)	Discharge-weighted average (mg/l) (high discharge) April-June	Discharge-weighted average (mg/l) (intermediate discharge) July-Oct.	Discharge-weighted average (mg/l) (low discharge) Nov.-March
Na	-	50.7	38.6	-
K	-	2.2	1.9	-
Ca	-	51.0	48.1	-
Mg	-	11.1	8.5	-
Al	-	-	-	-
SiO_2	-	6.6	6.6	-
HCO_3	-	68.8	70.9	-
SO_4	-	145.8	115.7	-
Cl	-	57.8	41.8	-
F	-	0.13	0.22	-
NO_3	-	0.08	0.08	-
Total	-	394.21	332.40	-
Average Monthly Discharge	409×10^3 c.f.s.			
Number of analyses	7	3	4	-

TABLE IV (cont'd)

COMPOSITION OF LAKE CLAIRE

Parameters	Annual Volume Weighted-Average (mg/l)	Volume-weighted average (mg/l) (high discharge) April-June	Volume-weighted average (mg/l) (intermediate discharge) July-Oct.	Volume-weighted average (mg/l) (low discharge) Nov.-March
Na	125.1	50.0	61.7	503
K	5.5	3.3	3.4	17.4
Ca	121.0	55.6	58.6	478.0
Mg	30.5	14.6	12.1	127.6
Al	-	-	-	-
SiO_2	6.1	1.55	5.04	19.8
HCO_3	243.5	106.1	99.9	1028
SO_4	246.0	114.4	123.6	947.0
Cl	176.8	76.4	82.3	715.0
F	0.25	0.11	0.23	0.53
NO_3	0.16	0.08	0.05	0.71
Total	954.91	422.14	446.92	3837.04
Average Monthly Volume	612.5×10^3 ac. ft.			
Number of analyses	18	6	8	4

TABLE IV (cont'd)

COMPOSITION OF PRAIRIE RIVER

Parameters	Annual Discharge-Weighted Average (mg/l)	Discharge-weighted average (mg/l) (high discharge) April-June	Discharge-weighted average (mg/l) (intermediate discharge) July-Oct.	Discharge-weighted average (mg/l) (low discharge) Nov.-March
Na	24.9	29.0	24.6	no discharge
K	2.28	2.95	2.23	" "
Ca	40.9	38.0	41.2	" "
Mg	9.1	11.0	8.8	" "
Al	-	-	-	" "
SiO_2	4.0	0.8	4.2	" "
HCO_3	117.5	96.1	119.2	" "
SO_4	51.2	63.7	50.2	" "
Cl	29.9	43.3	28.8	" "
F	0.13	0.11	0.13	" "
NO_3	0.13	0.02	0.14	" "
Total	280.34	284.98	279.50	
Average monthly Discharge	$2.283 \text{ c } 10^3$ c.f.s.			
Number of analyses	4	1	3	

TABLE IV (cont'd)

COMPOSITION OF LAKE MAMAWI

Parameters	Annual Volume Weighted-average (mg/1)	Volume-weighted average (mg/1) (high discharge) April-June	Volume-weighted average (mg/1) (intermediate discharge) July-Oct.	Volume-weighted average (mg/1) (low discharge) Nov.-March
Na	18.5	57.6	13.8	Dry
K	1.8	2.5	1.8	Dry
Ca	39.0	52.8	37.3	Dry
Mg	8.1	14.4	8.0	Dry
Al	0.10	-	0.11	Dry
SiO_2	3.6	0.6	3.9	Dry
HCO_3	113.7	123.1	112.5	Dry
SO_4	40.8	97.7	34.0	Dry
Cl	22.3	88.0	14.4	Dry
F	0.12	0.13	0.10	Dry
NO_3	0.03	-	0.03	Dry
Total	248.05	436.83	225.94	-
Average Monthly Volume	1.625×10^3 ac. ft.			
Number of analyses	4	1	3	-

of such a monitoring program is more evident on examination of the evaporation rates in this basin.

The evaporation rate of Lake Claire waters has been determined as 181,000 acre-feet per year for a 561,000 acre-feet average lake volume and for Lake Mamawi waters as 14,000 acre-feet per year for a 17,900 acre-feet average lake volume.

Lake Athabasca Basin

General Considerations

The Lake Athabasca Basin can be classed as a deep water open-basin fed by numerous streams with drainage basins entirely within the Canadian Shield and by the Athabasca River which predominantly drains over sedimentary rocks of the Western Sedimentary Basin.

The Athabasca River during high discharge periods carries substantial sediment loads which are being actively deposited in the extreme southwest portion of Lake Athabasca: consequently this portion of the lake is shallow when compared to the remainder of the lake.

Further, quality information from this study has shown that the Athabasca River waters entering this basin are not extensively mixed with waters from the Canadian Shield by the time they reach the lake outlet, the Riviere des Rochers.

Quality Considerations

The average chemical composition as weighted averages for total dissolved solids and for the chemical parameters of this basin on a high, intermediate, and low discharge or volume basis are presented in Table V.

The results show that the Athabasca River during low discharge periods carries more total dissolved solids per unit volume of water that it does during periods of intermediate and high discharge, and that during intermediate discharge periods it carries more total dissolved solids per unit volume than during periods of high discharge. Such results are typical of most Western Canadian rivers.

The results also show that the waters of the Athabasca River are characterized by relatively high contents of sodium, calcium, magnesium, sulfates, and chlorides. The contents of these ions can be considered significant in water quality standards when conpared to the contents of such ions in Canadian Shield waters. (Appendix A, Table II).

The increase in total dissolved solids during periods of low discharge per unit volume in the waters of the Athabasca River demonstrates the importance of groundwater inflow in this river during the winter periods.

The results show that the average chemical composition of West Lake Athabasca waters decrease with increased inflow of waters to the lake, a common phenomenon brought about by dilution. Whereas, during periods of intermediate and low discharge the chemical composition of the waters remained fairly constant.

TABLE V

LAKE ATHABASCA BASIN

COMPOSITION OF THE ATHABASCA RIVER

Parameters	Annual Discharge-weighted Average (mg/l)	Discharge-weighted average (mg/l) (high discharge) April-June	Discharge-weighted average (mg/l) (intermediate discharge) July-Oct.	Discharge-weighted average (mg/l) (low discharge) Nov.-March
Na	6.8	5.6	5.8	15.3
K	1.3	1.0	1.4	1.9
Ca	34.6	30.7	33.3	53.2
Mg	6.7	6.7	6.2	9.9
Al	-	-	-	-
SiO_2	5.2	4.3	6.0	4.5
HCO_3	119.4	106.9	112.7	192.2
SO_4	40.8	23.7	52.0	42.6
Cl	1.9	1.6	1.9	6.0
F	0.09	0.08	0.09	0.11
NO_3	0.04	0.06	0.01	0.14
Total	216.63	180.64	218.40	325.85
Average Monthly Discharge	850.1×10^3 c.f.s.			
Number of analyses	10	2	2	6

TABLE V (cont'd)

COMPOSITION OF WEST LAKE ATHABASCA

Parameters	Annual Volume Weighted-average (mg/l)	Volume-weighted average (mg/l) (high discharge) April-June	Volume-weighted average (mg/l) (intermediate discharge) July-Oct.	Volume-weighted average (mg/l) (low discharge) Nov.-March
Na	4.2	2.9	5.1	3.9
K	1.0	0.9	1.0	1.1
Ca	13.9	9.0	14.6	15.1
Mg	3.7	2.0	3.5	4.5
Al	-	-	-	-
SiO_2	4.0	2.6	3.3	5.1
HCO_3	49.5	22.5	55.5	54.0
SO_4	7.2	5.2	9.0	6.3
Cl	4.9	3.2	5.9	4.4
F	0.06	0.06	0.07	0.05
NO_3	0.07	0.02	0.04	0.11
Total	88.53	48.38	98.01	94.56
Average monthly volume	188.3×10^6 ac. ft.			
Number of analyses	13	2	5	6

TABLE V (cont'd)

COMPOSITION OF RIVERE DES ROCHERS

Parameters	Annual Discharge-weighted Average (mg/1)	Discharge-weighted average (mg/1) (high discharge) April-June	Discharge-weighted average (mg/1) (intermediate discharge) July-Oct.	Discharge-weighted average (mg/1) (low discharge) Nov.-March
Na	-	8.0	6.0	-
K	-	1.3	1.1	-
Ca	-	24.5	22.8	-
Mg	-	5.6	4.8	-
Al	-	-	-	-
SiO_2	-	3.6	4.5	-
HCO_3	-	90.1	83.6	-
SO_4	-	17.4	12.7	-
Cl	-	7.3	4.8	-
F	-	0.07	0.08	-
NO_3	-	1.51	0.05	-
Total	-	159.38	140.43	-
Average Monthly Discharge	67.7×10^3 c.f.s.			
Number of analyses	7	2	6	-

The waters of Lake Athabasca are shown to be relatively low in total dissolved solids and that they are not significantly affected by the discharge of relatively high total dissolved solid waters from the Athabasca River.

The Rivière des Rochers waters show higher contents of total dissolved solids per unit volume during periods of high discharge than during periods of intermediate discharge. These results indicate that this river is receiving high total dissolved solid waters from the Lake Claire - Lake Mamawi Basin during this period, in addition to waters from Lake Athabasca.

The total trace metal results presented for this basin (Appendix A, Table II) show insignificant quantities being discharged to the lake in waters of inflowing streams, in the lake waters, and in waters of outflowing streams.

Water Quality Ice Cover Survey

Peace-Athabasca Delta Complex

General Considerations

This survey was conducted during the period of maximum ice accumulation in the Delta complex for the 1971 winter season.

The average thickness of ice on the various water bodies in the Delta complex was 4.0 feet. Consequently small water bodies, such as Baril, Mamawi, Hilda, and Richardson Lakes were frozen throughout. Lake Claire was frozen to the bottom except for the central, the deepest, portion of the lake and this portion of the lake contained water at depths of only four inches. The extreme southwest portion of Lake Athabasca was

frozen to the bottom for approximately three miles into the lake from the south shore, except for small channels carrying Athabasca River waters. The water under the ice in the southwest portion of the lake was, on the average, approximately 16 inches in depth. Generally, the lake waters under the ice cover became deeper toward the north shore, in the vicinity of Fort Chipewyan, and towards the center of the lake in an easterly direction.

Detailed information on ice thickness and water depths for the Delta complex is given in Appendix B for the locations as indicated in Figure 2.

Quality Considerations

The locations of all on-site water quality samples are shown in Figure 2. The on-site water quality results (Appendix B, Table II) show the waters in Lake Claire to be devoid of dissolved oxygen and to contain dissolved salts in the order of 2,800 mg/l. The inflowing streams to this lake, Birch and McIvor, contained dissolved salts in the order of 1,000 mg/l and 2,400 mg/l and dissolved oxygen in the order of 3 mg/l and 4.5 mg/l, respectively. The outflowing river from this lake, the Prairie, contained dissolved salts in the order of 800 mg/l and dissolved oxygen in the order of 1.3 mg/l. These results are illustrated in Figure 4.

The on-site analytical data on the waters in the west end of Lake Athabasca (Appendix B, Table II) show that the waters entering the western portion of the lake from the Sedimentary Basin, and from Canadian Shield do not mix under ice-cover conditions. The Sedimentary Basin water contained dissolved in the order of 225 mg/l while the dissolved salts in the Canadian Shield

were in the order of 75 mg/l. The dissolved oxygen in these waters was in the order of 8 mg/l. The inflowing streams to the west end of this lake, Athabasca and Embarras, contained dissolved salts in the order of 255 mg/l and 568 mg/l, and dissolved oxygen in the order of 5.7 mg/l and 0.0 mg/l, respectively. The outflowing rivers from the west end of this lake, the Chenal des Quatre Fourches and Rivière des Rochers, contained dissolved salts in the order of 209 mg/l and 172 mg/l, and dissolved oxygen in the order of 5.6 mg/l and 8.0 mg/l, respectively. These results are also illustrated on Figure 4.

These results indicate a build-up of dissolved salts and reducing conditions in the waters of Lake Claire during the ice-cover period. Whereas, the waters in Lake Athabasca, west end, show no evidence of salt build-up and the dissolved oxygen levels are sufficient for most uses during ice-cover conditions.

The build-up of dissolved salts in Lake Claire from about 220 mg/l for the open water period to about 2,800 mg/l for the ice-cover period can be attributed to: inflowing streams with their water source entirely from ground waters, chemicals held in bottom sediments being released under reducing conditions, and the concentration of dissolved chemicals through ice formation. The dissolved salt content of the ice formed in Lake Claire in 1971 was 89.6 mg/l. (Appendix A, Table I).

The analytical data of the waters under the ice cover from selected locations in Lakes Claire and Athabasca during this survey are presented in Appendix B, Table II as indicated in Figure 4.

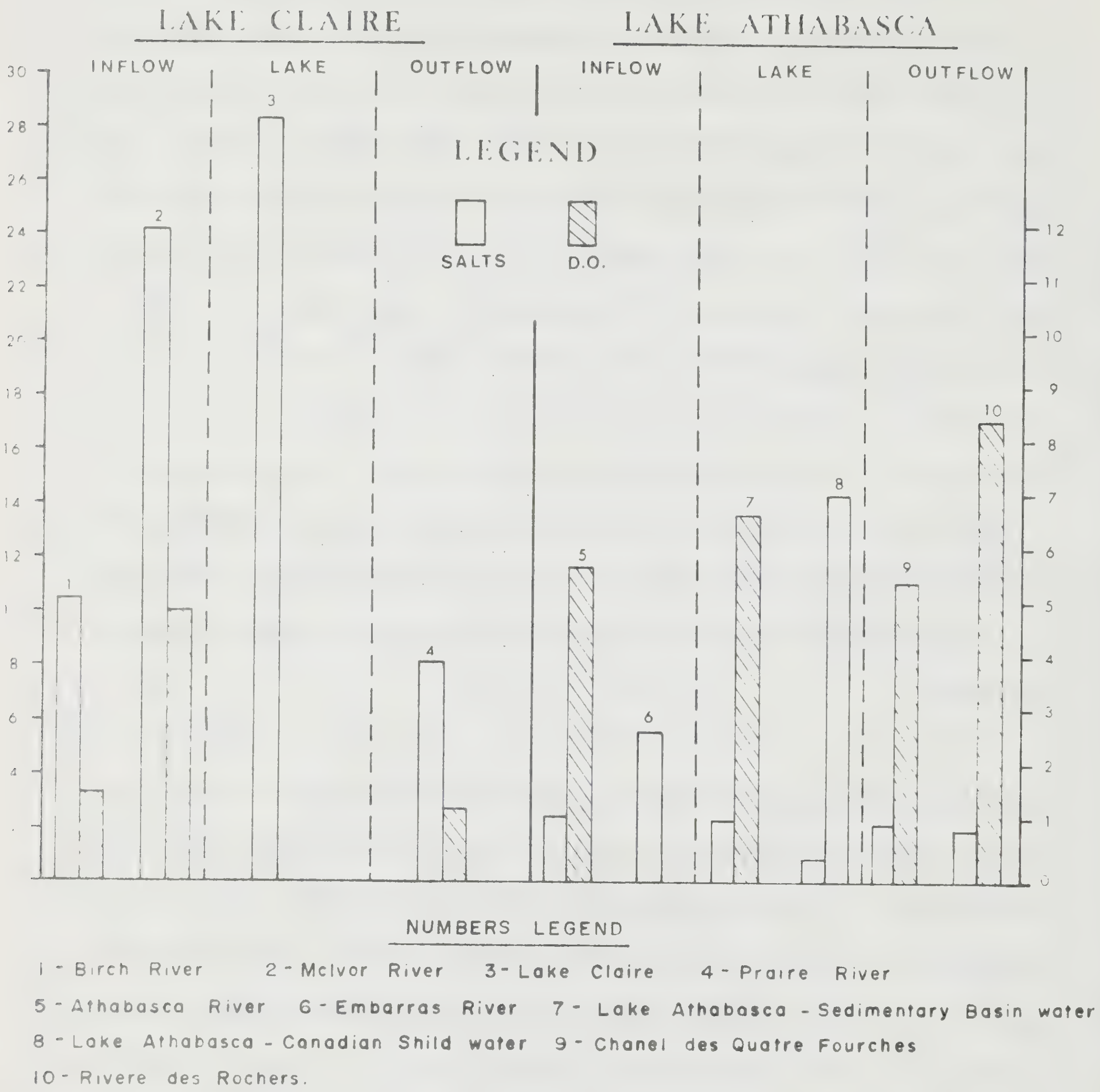


Fig 4 Salts imput and output for Lake Claire and dissolved oxygen levels of inflowing and outflowing rivers and the lakes, during 1971 ice-cover period.

These data show the waters in Lake Claire, under ice-cover to be hard and to contain relatively high concentrations of calcium, magnesium, sodium, potassium, bicarbonates, sulfates, and chlorides. In contrast, the waters in Lake Athabasca were soft and contained relatively low concentrations of these major ions. In addition, the waters of Lake Claire were shown to contain significant concentrations of barium, boron, carbon, copper, iron, lithium, manganese, strontium, nitrogen and phosphorus when compared to the significant concentrations of these elements found in the waters of Lake Athabasca.

The total dissolved salts concentration of the waters in Lake Claire under ice conditions make these waters unfit for human use, injurious to most aquatic plants, and detrimental for animal use. The anion content of the waters of this lake under ice conditions, especially the chlorides, are in the concentration range that can cause injury to most plants growing in the Delta complex, and may cause injury to any fine textured fish using the water.

Of the trace metals reported in this study for Lake Claire, boron, copper, iron, and manganese were detected in concentrations that may be detrimental for some uses. The boron concentrations were sufficiently high to be deleterious to the higher plants, copper was found in concentrations injurious to most plants and high enough to interfere with the self-purification process of the lake waters by bacteria, iron was detected in concentrations high enough to cause taste and aesthetic problems and to be above acceptable limits for supporting good fish fauna, and manganese was found in concentrations high enough to be considered harmful for most uses.

The chemistry of the waters of Lake Athabasca under ice conditions, in contrast to the water of Lake Claire, can be considered as good for all uses.

The nutrient elements, nitrogen, phosphorus, and carbon, were detected in quantities adequate for luxury plant growth in Lake Claire, and in quantities more than adequate for plant growth in Lake Athabasca.

Birch River, Lake Claire, Lake Athabasca

General Considerations

This survey was conducted in March, 1972 on request by the Fisheries Study Group for the purpose of determining the probability of the Birch River being used by fish to over-winter.

The sampling locations for this survey are shown in Figure 2 and the date and time of sampling and the ice thickness at each sampling location are given in Appendix B, Table I. Samples of Lakes Claire and Athabasca waters were also taken during this survey for comparisons.

Quality Considerations

The water quality results for this survey are given in Appendix B, Table III. These results show that, during the month of March, the waters of the Birch River contained dissolved oxygen levels ranging between 0.12 and 1.85 mg/l. Lake Claire waters showed 1.10 mg/l of dissolved oxygen, whereas the waters of Lake Athabasca contained 11.51 mg/l of dissolved oxygen.

These results disclose that the dissolved oxygen levels in the waters of the Birch River and of Lake Claire are insufficient to support fish during

1971-72 ice cover period, but that the Lake Athabasca waters contained sufficient dissolved oxygen to support a fish population.

Lake Sediment Survey

General Considerations

Lakes represent holding and mixing basins for stream flows. The detention time of water in lakes provide a potential opportunity for slow chemical reactions to come to completion, and for the precipitates that may be formed to settle and become incorporated in the lake sediments. This is particularly true for close-basin lakes.

The elements adsorbed on the sediments before and during deposition, and the chemical compounds incorporated in the sediments are a potential source of chemical constituents for aquatic life, and for release to the water system should conditions in lakes undergo a change from the oxidized to the reduced state.

It was felt this source of chemical constituent was important to the quality of the water in the Delta complex, consequently a minor sediment program was carried out to explore the magnitude of this source.

The sediments in the lakes in the Delta complex were collected during the month of November, 1971 at the locations shown in Figure 2.

Quality Considerations

The detailed analytical results for this survey are presented in Appendix C, Table I, whereas the median values for each parameter analyzed for each

lake within the Delta complex are presented in Table IV for ease of interpretation.

Water stored in lakes commonly is poorly mixed, consequently the sediments carried by the water entering the lakes will be segregated and/or indiscriminately mixed to form heterogeneous deposits. Single samples, therefore, of lake sediments can be assumed to represent only the spot within the deposit from which they come.

This survey was conducted to ascertain the potential only of the bottom sediments as a storehouse for natural and induced chemicals that may be hazardous to the Delta's eco-system. It was not intended to characterize the lake sediments in this survey.

The importance of the quantities of chemicals adsorbed and/or incorporated in the bottom sediments of the shallow lakes in the Delta complex has been demonstrated by the high concentrations of certain ions whose behavior is influenced by oxidation and reduction, as shown by the ice cover water quality survey. Under reducing conditions, the ice cover water quality survey has shown that certain chemicals held by sediments can be released to the overlying water resulting in concentrations deleterious to animals, plants, and aquatic organisms.

This preliminary survey of the lakes bottom sediments indicate that these sediments contain sufficient quantities of chemicals which, if released by reduction processes, would be harmful to the Delta's eco-system. (Table VI).

The median values for the major cations, calcium and magnesium, indicate that between 40 and 70 percent calcium and between 6 and 10 percent magnesium of the total acid soluble quantities of these elements were held in the sediments by the exchange phenomenon. These values also show that 30 to 40 percent manganese, 35 to 55 percent barium, 30 to 55 percent sodium, 10 to 25 percent potassium, and 50 percent strontium of the acid soluble quantities of these elements were held in the exchangeable form.

While only small quantities of aluminum, copper, iron, lead, lithium, mercury, and zinc were shown to be present on the exchange complex.

The significance of the exchangeable quantities of these elements in the sediments is the ease in which ion-exchange reactions take place between solutes and sediments when the chemical equilibrium of the system is out of balance.

The median values also show that the Lake Baril sediments contain the largest quantities of chemical constituents, followed by Lake Athabasca, then Lake Claire, and finally by Lake Mamawi. Lake Baril evaporates to dryness during low water levels and Lake Mamawi input is from Lake Claire only which would account for these variations. Lakes Athabasca and Claire have input from rivers and streams.

From the information gleaned from this preliminary survey, it is evident that a more extensive program on the chemistry of these sediments, as well as the quantity of the sediments being carried into the Delta lakes be

carried out immediately. The significance of such a program is increased many fold with the proposal to build structures for the control of the water level in the Delta complex.

TABLE VI

Median Values for Exchangeable and Acid Soluble Analysis of Sediments
Peace-Athabasca Delta Lakes
(mg/100 gms oven-dry weight)

PARAMETER	Lake Baril		Lake Athabasca		Lake Claire		Lake Mamawi	
	Exch.	Sol.	Exch.	Sol.	Exch.	Sol.	Exch.	Sol.
Aluminum	0.74	780	0.30	678	0.45	608	<0.10	492
Barium	8.9	16.0	5.0	13.0	4.2	8.8	4.3	8.7
Boron	0.22	-	0.09	-	0.16	-	0.13	-
Calcium	735	1110	1000	1240	552	1008	385	910
Copper	0.05	3.3	0.04	2.6	0.04	2.4	0.04	1.7
Iron	0.35	3030	0.37	2430	0.60	2045	0.14	1780
Lead	<0.10	1.9	<0.10	1.7	<0.10	1.5	<0.10	1.2
Lithium	0.03	1.7	0.02	1.6	0.03	1.4	0.02	1.0
Magnesium	63.0	665	43.0	650	55.0	562	45.0	550
Manganese	20.0	59.0	12.0	54.0	11.5	38.5	11.3	35.0
Mercury	0.0008	0.017	0.0003	0.016	0.0002	0.016	<0.00005	0.012
Potassium	23.0	97.0	12.0	92.0	18.0	81.0	13.5	93.0
Sodium	6.0	11.0	4.0	12.0	13.0	20.0	8.0	14.0
Strontium	2.2	4.5	2.8	5.5	2.6	5.2	1.7	3.7
Zinc	0.20	12.5	0.30	10.0	0.35	9.0	0.16	7.0

CHEMICAL LOADINGS AND CHEMICAL BALANCES

General

The chemical loadings of the parameters presented in this report were calculated on the basis that one milligram per liter of a chemical constituent in water is equivalent to 0.0012336 metric tons per acre-foot. Thus,

mg/l. x 0.0012336 x acre-feet = loading in metric tons

In order to carry out these calculations, the following assumptions were necessary:

1. The chemical quality of the water remained constant throughout each month;
2. The chemical quality of the delta waters during the 1972 winter period was identical to the 1971 winter quality data;
3. There was no inflow water from the Peace River;
4. The Birch River contributed 80.8 percent and McIvor River contributed 19.2 percent of the total inflow waters to Lake Claire.
5. In the five-year hypothetical sequence, all inflow waters came from the Birch and McIvor River Basins and all outflow waters were as streamflow in the Chenal des Quatre Fourches;
6. The yearly average water composition remained constant for the period 1971 to 1977.

Lake Claire and Lake Mamawi were considered as two separate basin systems for calculating the chemical loading and chemical balances for the 1971 period, but the two basin systems were considered as one basin system by a structure on the Chenal des Quatre Fourches at Doghead for the loadings and balances for the five-year hypothetical sequence.

The chemical loadings and chemical balances for the Lake Athabasca basin system could not be calculated because of insufficient flow data.

Chemical Loadings

Lake Claire and Lake Mamawi Basin Systems, 1971

The chemical loading results by the month and by the year for each parameter, and the total dissolved solids loadings by the month and by the year for the Lakes Claire and Mamawi Systems are presented in Appendix D , Table I .

These results show that the yearly total dissolved solids discharged to Lake Claire are in the order of 208 x 10^3 metric tons from the Birch River Basin and 56.3 x 10^3 metric tons from the McIvor River Basin, making a total of 264.3 x 10^3 metric tons of dissolved solids discharged yearly to Lake Claire.

The Birch River Basin is shown to discharge to Lake Claire, yearly, in the order of 26.9 x 10^3 metric tons of calcium, 6.3 x 10^3 metric tons of magnesium, 38.9 x 10^3 metric tons of sodium, 52.8 x 10^3 metric tons of chlorides, and 45 x 10^3 metric tons of sulfates, in comparison to 8.6 x 10^3metric tons of calcium, 1.6 x 10^3 metric tons of magnesium, 7.5 x 10^3 metric tons of sodium, 8.3 x 10^3 metric tons of chlorides, and 2.2 x 10^3 metric tons of sulfates discharged yearly to Lake Claire for the McIvor River Basin. These results indicate that the yearly total dissolved solids contribution to Lake Claire from the Birch and McIvor River Basins are the order of a 4 to 1 ratio. The sodium-calcium-magnesium ratio is shown to be 6.6-4.5-1 for the Birch River Basin

and 3-4.5-1 for the McIvor River Basin, and the chlorides-sulfates ratio is shown to be 1.2-1 for the Birch River Basin and 4-1 for the McIvor River Basin.

The results also show that the yearly total dissolved solids discharged from Lake Claire to the Prairie River was in the order of 174 x 10^3 metric tons. Of this total, the lake discharged 28.2 x 10^3 metric tons of calcium, 6.9 x 10^3 metric tons of magnesium, 23.2 x 10^3 metric tons of sodium, 30.8 x 10^3 metric tons of chlorides, and 41.3 x 10^3 metric tons of sulfates. The discharge ratio of sodium-calcium-magnesium was 3.3-4.01 and for chlorides-sulfates it was 1-1.3.

Lake Claire also received in metric tons 0.14 x 10^3 boron, 0.46 x 10^3 iron, 0.01 x 10^3 manganese, 1.8 x 10^3 potassium, 4.7 x 10^3 silica, 1.2 x 10^3 nitrogen, and 0.37 x 10^3 phosphorus, and discharged 0.6 x 10^3 boron, 0.02 x 10^3 iron, 0 x 10^3 manganese, 1.7 x 10^3 potassium, 2.3 x 10^3 silica, 0.7 x 10^3 nitrogen, and 0.42 phosphorus. The amounts of copper, lead, and zinc discharged to the lake are considered insignificant.

The results of the chemical loadings to Mamawi Lake from the Prairie River and Chenal des Quatre Forches show the lake received in the order of 211 x 10^3 metric tons of total dissolved solids. Of this total, the lake received in metric tons 35.2 x 10^3 calcium, 8.6 x 10^3 magnesium, 27.2 x 10^3 sodium, 35.9 x 10^3 chlorides, and 48 x 10^3 sulfate. The ratio of sodium-calcium-magnesium received by the lake was 2.6-4-] and for chlorides-sulfates it was 1-1.3.

During this period Lake Mamawi discharged to the Chenal des Quatre Fourches in the order of 173.9 x 10^3 metric tons of total

dissolved solids composed of, in metric tons, 31.8 x 10^3 calcium, 7.5 x 10^3 magnesium, 19.3 x 10^3 sodium, 24.7 x 10^3 chlorides, and 32.7 x 10^3 sulfates. The ratio of sodium-calcium-magnesium discharged by the lake was 2.5-4.3-1 and for chlorides-sulfates it was 1-1.3.

In addition, Lake Mamawi received, in metric tons, 0.07 x 10^3 boron, 0.03 x 10^3 iron, 2.0 x 10^3 potassium, 3.0 x 10^3 silica, 0.9 x 10^3 nitrogen, and 0.5 x 10^3 phosphorus, and discharged 0.05 x 10^3 boron, 0.02 x 10^3 iron, 1.6 x 10^3 potassium, 3.0 x 10^3 silica, 0.8 x 10^3 nitrogen, and 0.3 x 10^3 phosphorus. Insignificant amounts of copper, lead, and zinc were received and discharged by this system.

Lake Claire-Lake Mamawi Basin Systems, Five-Year Hypothetical Sequence

The chemical loading results by the year for each parameter and the total dissolved solids loading by the year for this system are presented in Appendix D , Table II .

The results show that for the five-year sequence the system received 2,071.7 x 10^3 metric tons and discharged 1,351 x 10^3 metric tons of total dissolved solids. The major ions comprising these totals, in metric tons, were:

(a) Received - 320.5 x 10^3 calcium, 63.8 x 10^3 magnesium, 316.8 x 10^3 sodium, 370.3 x 10^3 chlorides, and 670.8 x 10^3 sulfates.

(b) Discharged - 255.2 x 10^3 calcium, 60.4 x 10^3 magnesium, 141.1 x 10^3 sodium, 174.6 x 10^3 chlorides, and 241.1 x 10^3 sulfates.

The ratios of sodium-calcium-magnesium received were 5-5-1 and for chlorides-sulfates, 1-1.8. These ratios for discharges were 2.4-4.2-1 and 1-1.4, respectively.

In addition, the system received, in metric tons, 1.0×10^3 boron, 0.02×10^3 copper, 3.1×10^3 iron, 0.007×10^3 lead, 0.1×10^3 manganese, 14.8×10^3 potassium, 42.3×10^3 silica, 0.02×10^3 zinc, 9.2×10^3 nitrogen, and 2.6×10^3 phosphorus. During the same period the system discharged, in metric tons, 0.3×10^3 boron, 0.01×10^3 copper, 0.2×10^3 iron, 12.1×10^3 potassium, 26.9×10^3 silica, 0.006×10^3 zinc, 6.6×10^3 nitrogen, and 2.7×10^3 phosphorus.

Chemical Balances

Lake Claire and Lake Mamawi Basin Systems, 1971

The results of the chemical balances by parameters and by the year are presented in Appendix D , Table III .

These results show that the Lake Claire System received 264,247.9 metric tons, discharged 174,089.1 metric tons, and retained 90,158.8 metric tons of dissolved solids during the 1971 period.

The results also show that the system retained 59% boron, 0.6% calcium, 13% copper, 95% iron, 100% lead, 100% manganese, 5% potassium, 13% magnesium, 50% sodium, 50% silica, 50% chlorides, 40% total nitrogen, 84% nitrates, and 39% sulfate of the total metric tons of these elements discharged to the system. In addition, the system discharged 109% zinc, 113% total phosphates, and 103% bicarbonates.

For the Lake Mamawi System, the results show the system received 211,270.9 metric tons, discharged 173,888.2 metric tons, and retained 37,382.6 metric tons of dissolved solids during the 1971 period.

This system is shown to retain 30% boron, 9% calcium, 27% copper, 30% iron, 21% potassium, 12% magnesium, 29% sodium, 9% zinc, 31% chlorides, 7% total nitrogen, 34% total phosphates, and 32% sulfates of the total metric tons of these elements discharged to the system. In addition, the system discharged 102% silica, 396% nitrates, and 103% bicarbonates.

Of the total dissolved solids retained in Lake Claire 25.7% is sodium, 8.1% is calcium, 1.1% is magnesium, 33.6% is chlorides, 28.7% is sulfates, 2.6% is silica and the remaining 0.2% contains the remainder of the elements.

For Lake Mamawi, the total dissolved solids retained by the lake is composed of 21.3% sodium, 8.9% calcium, 2.8% magnesium, 29.7% chlorides, 37.0% sulfates, and the remaining 0.3% contains the remainder of the elements.

The above percentages show that the quantities of ions retained by Lake Claire, in order of descending values, are sodium, calcium, and magnesium for the cations, and chlorides, sulfates, and silica for the anions, but in Lake Mamawi the order of descending values are sodium, calcium, and magnesium for the cations, and sulfates and chlorides for the anions.

Lake Claire - Lake Mamawi Basin System, 5 Year Hypothetical Sequence

The results of the chemical balances by parameters for the 5-year sequence are presented in Appendix D , Table III .

The results indicate that this system will receive 2,071,680.3 metric tons, will discharge 1,351,250.7 metric tons, and will retain 720,429.5 metric tons of dissolved solids over the 5-year period.

The results also indicate the system will retain 68% boron, 20% calcium, 40% copper, 95% iron, 100% lead, 100% manganese, 18% potassium, 5% magnesium, 55% sodium, 36% silica, 70% zinc, 53% chlorides, and 28% total

nitrogen. In addition the system will discharge 528% nitrates, 103% total phosphates, and 167% bicarbonates.

Of the total dissolved solids that will be retained by the system, 19.3% will be sodium, 7.1% calcium, 0.4% magnesium, 21.3% chlorides, 47.1% sulfates, and the remaining 4.8% will contain the remainder of the elements.

The above percentages show that the quantities of ions that will be retained in the system, in order of descending values, are sodium, calcium, and magnesium for the cations, and sulfates and chlorides for the anions.

General Discussion

Salts and ions retained in a system such as the Athabasca Delta may be taken up and/or lost to the system by aquatic plants and organisms, terrestrial plants and animals, and to a small degree by evaporation. They may also be sorbed on suspended and bottom sediments, both organic and mineral, and incorporated in the bottom sediment as precipitates of the less soluble salts.

The results of the chemical loading to the delta's water systems show the greatest quantities of ions being transported as sodium, calcium, magnesium, bicarbonates, chlorides, and sulfates.

The salts of sodium are highly soluble and once sodium has been brought into solution, it tends to remain in that status. There are no important precipitation reactions that can maintain low sodium concentrations in water. However, sodium is retained in systems by adsorption on clays and organic materials. The rate of adsorption depends on the concentration of the ion in the water and the degree to which the ion is held on the exchange complex, but there is a limit to the quantity of sodium held in the system by adsorption.

When the exchange complex of the clays and organic materials are in equilibrium with the sodium content in the water, the sodium content in the water will increase until a concentration is reached where further exchange will take place and the process can continue until the exchange complex is saturated with sodium. While this process continues there will be a slow increase in the concentration of sodium in the waters, but when sodium saturation of the exchange complex is achieved the increase in sodium content in the waters of this system will be greatly accelerated.

The minor survey results of the sediments presented in Appendix C Table I , show that the exchange complex of the bottom sediments of these systems are approximately 4% saturated with sodium, and with the major ions adsorbed being calcium, magnesium, and potassium.

To replace the calcium, magnesium, and potassium ions on the exchange complex will require higher concentrations of sodium in the systems waters, but if the concentrations of sodium being discharged to these systems by inflowing streams continues, approximately 46,000 metric tons per year, this required concentration may be reached rather quickly. However, due to sodium uptake by living organisms in the system and losses by evaporation, the rate of sodium increase in these systems can only be accurately determined by a monitoring program.

Because of the high concentrations of sodium being discharged to these systems yearly and the toxicity of the salts of sodium, such as sodium chloride, sodium bicarbonates, and sodium sulfates, to the present aquatic plants and organisms, and terrestrial plants and animals of the delta complex, it is considered essential to monitor these systems for sodium buildup and

particularly so if structures are to be built for water level control. It is also considered essential that any structures built have controls that can release buildup waters, when salt concentrations in these waters reach levels that can damage the delta's eco-system.

The concentrations of the other ions being discharged to these systems, such as calcium, magnesium, boron, generally do not reach high concentration in waters due to mechanisms within the system that cause the salts of these ions to precipitate and to be incorporated and buried in the bottom sediments. The results of the acid soluble analysis of the sediments, Appendix C, Table I show the effectiveness of these mechanisms.

CONCLUSIONS

This brief study serves mainly to point out the potential hazard of chemical build-up in the basin systems of the Peace-Athabasca Delta Complex through the chemical composition of inflowing stream waters, and through evaporation of the delta's water bodies.

The results of this study are based on the chemical quality of the delta waters during the 1971 water year which is considered to be a low water yield year by hydrologists, thus the chemical loading results as presented in this report could be somewhat different to chemical loading results for an average water yield year.

The results obtained from this study demonstrate the importance of water quality considerations when studying eco-systems such as the Peace-Athabasca Delta by bringing to light the increased concentration of sodium and chloride ions in the waters discharged to the delta's water bodies and the loadings of these ions to the delta's systems which can pose a problem in managing the water resources of the delta complex.

The study demonstrates that a potential hazard exists through chemical build-up of salts in the Lake Claire and Mamawi Basin Systems to that portion of the delta's eco-system encompassed by these systems. It also demonstrated the need for further studies to determine the source of the chemical ions and chemical salts retained by the system and the chemical forms these

elements take when incorporated in bottom sediments.

Because this study falls short of determining the source of the chemical constituents retained by the delta's water systems due to a time restraint placed on the study, the chemical build-up in the water bodies of the delta cannot be accurately assessed. Therefore, a water quality monitoring program of the delta's water bodies is essential to accurately plot the chemical hydrology, especially for those water bodies affected by control structures, to adequately protect the delicate eco-system of this delta.

RECOMMENDATIONS

The results of this preliminary study have shown that the chemical input to the waters in the delta's reservoirs by inflowing streams poses a potential hazard to the ecology of the delta complex.

For the protection of the delta's ecology against this potential hazard, the following water quality measures are recommended:

1. A semimonthly monitoring program for Lakes Claire and Mamawi be initiated immediately to monitor the concentrations of total dissolved solids, major ions, pH, and dissolved oxygen, supplemented by a program to determine the trace metal concentrations seasonally.

2. Establish water quality and quantity monitoring stations on key inflowing streams to the delta for the purpose of obtaining more accurate information on chemical loading to the delta's water basin systems through long-term records.

3. A study be initiated on the delta reservoirs to determine the mechanisms and methods of retention and/or loss of chemicals constituents to the basin systems.

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APPENDIX A

TABLE I

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

INFLOWING RIVERS OF LAKE CLAIRE

Birch River

Al	(mg/l)	<0.08	0.08	<0.08	0.10	0.09	<0.08	0.11	0.21	0.26
B	(mg/l)	0.13	0.14	0.16	0.15	0.21	0.21	0.04	-	0.33
Ba	(mg/l)	<0.04	<0.04	0.08	<0.04	0.09	<0.04	0.048	0.016	0.015
Ca	(mg/l)	20.0	31.7	40.1	19.6	31.4	45.1	20.0	-	77.3
Cd	(mg/l)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.11	<0.0005	<0.0005	0.002
Co	(mg/l)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.003
Cr	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/l)	0.004	0.002	0.002	0.005	0.004	<0.001	0.001	0.006	0.010
Fe	(mg/l)	0.54	0.58	0.17	0.32	0.25	0.54	0.66	3.8	4.3
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.017
Li	(mg/l)	0.014	0.025	0.032	0.011	0.022	0.051	0.023	0.083	0.092
Hg (total)	(mg/l)	0.00005	<0.00005	<0.00005	<0.00005	0.00018	0.00018	<0.00005	<0.00005	-
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00010	<0.00005	-	-
Mn	(mg/l)	0.055	<0.015	<0.015	<0.015	<0.015	<0.015	0.023	0.52	0.78
Mg	(mg/l)	6.1	7.8	10.5	2.5	8.0	11.8	3.9	-	23.0
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-
Ni	(mg/l)	<0.006	0.008	<0.006	<0.006	<0.006	<0.006	<0.006	0.008	0.011
K	(mg/l)	2.2	2.2	2.5	1.1	1.4	2.2	1.1	-	3.2
SiO2	(mg/l)	3.5	3.4	4.0	4.6	5.7	4.0	5.9	-	9.8
Na	(mg/l)	21.5	36.5	49.2	9.8	31.6	92.0	43.0	-	180
Sr	(mg/l)	0.15	0.25	0.31	0.10	0.21	0.41	0.19	0.92	0.96
Tl	(mg/l)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	0.24	<0.001	<0.001	0.004
Total Cations	(mg/l)	2.5203	3.9173	5.0780	1.6553	3.1807	7.3372	3.2529	-	13.8921
Cl	(mg/l)	26.4	49.5	70	9.9	32.0	140.0	57.5	-	250
F	(mg/l)	0.09	0.11	0.15	0.13	0.10	0.16	0.09	-	-
HCO3	(mg/l)	57.1	74.6	110.7	31.9	68.5	114.0	47.9	-	796.4
N	(mg/l)	1.06	1.21	1.20	2.39	0.74	0.87	0.62	-	0.09
NO3 + NO2	(mg/l)	0.02	<0.01	<0.01	0.10	0.05	0.01	0.03	-	-
PO4 (ortho filt)	(mg/l)	0.05	0.02	0.02	0.03	0.02	0.02	0.03	-	0.090
PO4 (inorg filt)	(mg/l)	0.09	0.05	0.03	0.04	0.05	0.04	0.07	-	0.13
PO4 (total)	(mg/l)	0.31	0.12	0.12	1.3	0.16	0.17	0.24	-	-
SO4	(mg/l)	38.8	60.9	60	41.3	56.0	70.4	41.9	-	115
Total Anions	(me/l)	2.4907	3.8880	5.0399	1.6707	3.1946	7.2771	3.2794	-	14.0185
Total Diss Solids	(mg/l)	146.8	228.9	291.0	105.1	194.2	421.9	197.1	-	796.4
Total Organic C	(mg/l)	26	28	25	34	31	23	38	-	33
Total Inorg. C	(mg/l)	10	12	18	6	11	20	5	-	45
Sampling Temperature	(°C)	11.1	16.8	20.0	17.9	22.3	10.2	2.8	0.5	0.3
Conductivity (field)	(uohms/cm)	-	-	-	316	-	1035	437	825	-
(lab)	(uohms/cm)	253	409	484	161	364	780	341	-	1324
pH (field)		-	-	-	6.7	-	7.6	7.1	7.3	-
(lab)		7.0	7.2	7.7	7.2	7.8	7.7	6.7	-	7.1
Color		150	110	65	180	-	180	340	-	260
Turbidity	(JTU)	35	6.2	5.2	140	15	11	23	-	5.5
Residue										
(non-filt. 105°C)	(mg/l)	48	2.0	7.2	728	10.2	6.2	40.8	-	-
(non-filt. 550°C)	(mg/l)	40	<0.2	3.0	665	3.4	3.6	32.4	-	
Alkalinity	(tot $CaCO_3$)	46.8	61.2	90.8	26.2	56.2	93.5	39.3	-	230
Hardness	(tot $CaCO_3$)	75.2	112.0	144.0	59.7	112.0	162.0	66.3	-	289
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		95	60	41	82	23	139	89	1.1	0.6
Data Collected	(D/M/Y)	10/05/71	24/05/71	7/06/71	7/07/71	9/08/71	30/08/71	5/10/71	26/02/71	15/03/71

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACEWATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

INFLOWING RIVERS OF LAKE CLAIRE

McIvor River

Al	(mg/l)	<0.08	<0.08	<0.08	1.4	0.07	<0.08	<0.08
B	(mg/l)	0.11	0.13	0.12	0.20	0.17	0.18	0.05
Ba	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05
Ca	(mg/l)	38.0	67.8	42.5	30.7	75.2	57.7	42.0
Cd	(mg/l)	0.0014	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/l)	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	(mg/l)	<0.02	<0.02	<0.02	0.078	<0.02	<0.02	<0.02
Cu	(mg/l)	0.005	<0.001	0.003	0.006	0.004	<0.001	0.003
Fe	(mg/l)	0.41	0.08	0.21	0.89	0.06	0.37	0.38
Pb	(mg/l)	<0.008	<0.008	<0.008	0.009	<0.008	<0.008	<0.008
Li	(mg/l)	0.022	0.038	0.027	0.024	0.037	0.026	<0.003
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	0.00044	0.00078	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	0.025	0.037	<0.015	0.030	<0.015	<0.015	<0.015
Mg	(mg/l)	8.6	14.7	8.5	6.0	15.3	10.2	6.4
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/l)	<0.006	0.007	0.008	<0.006	<0.006	<0.006	0.010
K	(mg/l)	2.05	2.5	2.0	3.3	2.2	1.5	1.3
SiO_2	(mg/l)	5.7	7.6	6.6	5.8	9.0	6.6	6.8
Na	(mg/l)	30.0	76	40.1	21.1	69.0	52	26
Sr	(mg/l)	0.20	0.30	0.16	0.15	0.35	0.28	0.16
Tl	(mg/l)	<0.15	<0.15	<0.15	<0.15	<0.15	0.24	<0.15
Zn	(mg/l)	0.005	<0.001	0.008	0.004	0.002	0.003	0.002
Total Cations	(me/l)	3.9978	7.9855	4.6267	3.0755	8.0965	6.0616	3.8159
Cl	(mg/l)	31.9	87	50.2	14.5	76.8	63	25
F	(mg/l)	0.18	0.027	0.22	0.22	0.28	0.22	0.19
HCO_3	(mg/l)	47.3	93.5	55.4	35.5	125.6	97.8	53.2
N	(mg/l)	1.42	0.72	1.57	2.79	0.75	1.08	0.90
$NO_3 + NO_2$	(mg/l)	0.04	0.05	0.22	0.17	0.02	0.03	0.08
PO_4 (ortho filt)	(mg/l)	0.05	0.03	0.05	0.04	0.04	0.05	0.03
PO_4 (inorg filt)	(mg/l)	0.07	0.04	0.06	0.05	0.05	0.07	0.05
PO_4 (total)	(mg/l)	0.12	0.38	0.12	0.16	0.42	0.68	0.59
SO_4	(mg/l)	115	192	110	92.9	183	125	105
Total Anions	(me/l)	4.0772	7.9787	4.6247	2.9386	8.0429	5.9885	3.7721
Total Diss Solids	(mg/l)	254.9	493.9	288.4	192.8	492.7	364.5	239.2
Total Organic C	(mg/l)	22	20	29	44	19	32	32
Total Inorg. C	(mg/l)	9	16	11	6	20	19	8
Sampling Temperature	(°C)	6.8	15.0	22.3	15.7	16.8	16.8	3.3
Conductivity (field)	(uohms/cm)	-	-	-	336	-	671	542
(lab)	(uohms/cm)	421	785	520	304	750	618	345
pH (field)		-	-	-	6.9	-	7.7	7.3
(lab)		7.0	7.4	7.5	7.2	7.7	7.5	7.0
Color		75	35	90	100	65	130	140
Turbidity	(JTU)	115	80	130	175	84	61	95
Residue								
(non-filt. 105°C)	(mg/l)	452	122	442	1710	156	175	285
(non-filt. 550°C)	(mg/l)	399	109	315	1673	137	157	258
Alkalinity	(tot $CaCO_3$)	38.8	76.7	45.4	29.1	103	80.2	43.6
Hardness	(tot $CaCO_3$)	131	231	142	102	252	187	132
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	21	23	10	19	5	33	21
Data Collected	(D/M/Y)	10/05/71	24/05/71	1/06/71	7/07/71	9/08/71	30/08/71	5/10/71

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

LAKE CLAIRE

			South				South East			*
Al	(mg/1)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.13
B	(mg/1)	0.10	0.07	0.08	0.09	0.16	0.13	0.18	0.13	-
Ba	(mg/1)	0.05	0.07	<0.04	0.08	0.06	0.061	<0.04	0.04	<0.04
Ca	(mg/1)	85.6	70.3	54.1	56.8	42.7	71.9	70.1	56.7	14.6
Cd	(mg/1)	<0.0005	0.017	<0.0005	<0.0005	<0.0005	<0.0005	0.012	<0.0005	<0.0005
Co	(mg/1)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004
Cr	(mg/1)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/1)	0.004	0.003	0.002	0.002	0.004	0.003	0.001	0.003	0.004
Fe	(mg/1)	0.14	<0.04	0.04	0.02	0.13	0.02	0.03	0.07	<0.01
Pb	(mg/1)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/1)	0.030	0.035	0.025	<0.003	0.028	0.030	0.057	0.028	0.006
Hg (total)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00044	0.00011	<0.00005	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Mn	(mg/1)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.06
Mg	(mg/1)	23.5	12.7	12.1	11.7	8.7	11.7	15.5	12.3	3.3
Mo	(mg/1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/1)	<0.006	<0.006	0.008	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
K	(mg/1)	4.9	3.5	3.1	3.2	3.2	3.6	3.2	2.7	0.8
SiO2	(mg/1)	3.9	5.8	1.3	1.5	5.5	6.2	3.8	4.9	0.6
Na	(mg/1)	44.3	71.0	53.0	58.8	35.8	72.0	79.0	69.0	14.4
Sr	(mg/1)	0.40	0.48	0.25	0.37	0.20	0.37	0.44	0.31	0.08
Ti	(mg/1)	<0.15	0.15	<0.15	<0.15	<0.15	<0.15	0.24	<0.15	<0.15
Zn	(mg/1)	0.004	0.001	0.002	0.003	0.010	0.002	0.002	<0.001	0.004
Total Cations	(me/1)	8.2644	7.7307	6.0819	6.4375	4.4925	7.7754	8 2930	6.9154	1.6469
Cl	(mg/1)	82	101	79	88	35.4	94	104	103	18.9
F	(mg/1)	0.18	0.26	0.19	0.18	0.28	0.25	0.30	0.24	0.09
HCO3	(mg/1)	105.8	110.0	97.3	107.2	48.8	120.7	130.7	86.2	29.6
N	(mg/1)	2.25	0.93	1.94	1.25	3.80	1.16	0.75	0.95	0.61
NO3 + NO2	(mg/1)	0.01	0.06	0.17	0.02	0.13	0.02	<0.01	0.07	-
PO4 (ortho filt)	(mg/1)	0.03	0.03	0.02	0.02	0.08	0.03	0.01	0.03	<0.010
PO4 (inorg filt)	(mg/1)	0.05	0.03	0.03	0.03	0.08	0.03	0.02	0.04	<0.010
PO4 (total)	(mg/1)	0.91	0.50	0.98	0.65	1.6	0.62	0.29	0.80	0.090
SO4	(mg/1)	200	147	109	108	128.6	151	150	130	31.0
Total Anions	(me/1)	8.2151	7.7180	6.0985	6.4895	4.4892	7.7794	8.2060	7.0294	1.6674
Total Diss Solids	(mg/1)	496.6	466.0	360.5	381.1	284.6	470.2	490.3	421.6	98.3
Total Organic C	(mg/1)	26	23	33	18	42	16	14	19	-
Total Inorg. C	(mg/1)	20	12	17	20	7	17	20	16	-
Sampling Temperature	(°C)	11.1	-	16.8	19	18.3	15.8	17.8	5.6	-
Conductivity (field)	(uohms/cm)	-	-	-	-	316	-	575	525	-
(lab)	(uohms/cm)	820	812.6	630	620	467	750	855	479	190
pH (field)		-	-	-	-	6.9	-	7.8	7.0	-
(lab)		7.2	7.9	7.4	7.6	7.3	7.7	7.9	7.3	7.1
Color		35	50	25	25	70	25	25	60	10
Turbidity	(JTU)	54	98	125	87	170	117	21	120	9.0
Residue										
(non-filt. 105°C)	(mg/1)	186	142	461	150	1830	233	30.2	212	14.0
(non-filt. 550°C)	(mg/1)	159	117	400	126	1670	208	25.8	182	7.2
Alkalinity	(tot CaCO3)	86.8	90.2	79.8	87.9	40.0	99.0	107.2	70.7	24.3
Hardness	(tot CaCO3)	313	229	186	191	143	229	240	193	50.2
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	520	600	580	620	660	770	710	620	420
Data Collected	(D/M/Y)	10/05/71	28/10/71	24/05/71	7/06/71	7/07/71	9/08/71	30/08/71	5/10/71	26/02/72

* Composite depth ice sample

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

LAKE CLAIRE

		Middle West				Middle East	
Al	(mg/1)	<0.08	0.10	0.13 *	0.26	<0.08	<0.08
B	(mg/1)	0.48	0.03	-	0.27	1.15	0.07
Ba	(mg/1)	0.25	0.05	<0.04	0.16	0.66	0.07
Ca	(mg/1)	128	46.9	6.7	151	778	58.8
Cd	(mg/1)	<0.0005	0.014	<0.0005	0.002	0.001	0.014
Co	(mg/1)	<0.002	0.04	0.018	0.002	<0.002	<0.002
Cr	(mg/1)	<0.02	0.013	<0.02	0.018	<0.02	<0.02
Cu	(mg/1)	0.008	0.003	0.007	0.014	0.019	0.003
Fe	(mg/1)	0.21	0.12	0.14	0.30	0.11	<0.04
Pb	(mg/1)	<0.008	0.008	<0.008	0.007	<0.008	<0.008
Li	(mg/1)	0.12	0.031	0.011	0.075	0.32	0.027
Hg (total)	(mg/1)	<0.00005	<0.00005	<0.00005	-	<0.00008	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	-	-	0.0007	<0.00005
Mn	(mg/1)	4.8	0.016	0.08	0.61	7.5	<0.015
Mg	(mg/1)	38.9	11.2	2.3	28.3	209.4	13.2
Mo	(mg/1)	<0.05	0.04	<0.05	-	<0.05	<0.05
Ni	(mg/1)	<0.006	<0.006	<0.006	0.010	<0.006	<0.006
K	(mg/1)	5.0	2.8	4.6	9.0	22.5	4.4
SiO_2	(mg/1)	14.0	5.9	0.4	1.2	22.1	4.9
Na	(mg/1)	250	56.6	21.3	150	750	52.2
Sr	(mg/1)	1.2	0.47	0.09	0.91	3.3	0.31
Ti	(mg/1)	1.2	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/1)	0.004	0.001	0.013	0.017	0.01	0.001
Total Cations	(me/1)	20.6013	5.8018	1.5720	16.6341	89.2537	6.4032
Cl	(mg/1)	361	78.6	27.3	199	1075	72.6
F	(mg/1)	0.21	0.18	<0.05	-	0.75	0.19
HCO3	(mg/1)	384.0	103.6	18.5	337.7	1611.5	139.0
N	(mg/1)	15.21	1.07	0.26	-	-	0.82
$NO_3 + NO_2$	(mg/1)	0.01	0.05	-	0.18	2.8	0.08
PO4 (ortho filt)	(mg/1)	0.02	0.02	2.1	<0.010	0.02	0.02
PO4 (inorg filt)	(mg/1)	0.05	0.03	2.1	0.013	0.10	0.02
PO4 (total)	(mg/1)	1.4	0.40	2.1	-	0.58	0.35
SO4	(mg/1)	205	89.1	9.1	243	1540	101.0
Total Anions	(me/1)	20.7228	5.7742	1.2606	16.1913	88.7544	6.4342
Total Diss Solids	(mg/1)	1191.3	342.6	80.8	947.8	5190.7	376.1
Total Organic C	(mg/1)	70	30	-	35	190	17
Total Inorg. C	(mg/1)	65	14	-	58	215	14
Sampling Temperature	(°C)	0	-	-	0.3	0	-
Conductivity (field)	(uohms/cm)	910	-	-	-	>2000	-
(lab)	(uohms/cm)	1080	600	106	1566	6940	643
pH (field)		7.3	-	-	-	8.1	-
(lab)		7.6	7.8	6.5	8.6	8.0	8.1
Color		95	80	40	65	140	20
Turbidity	(JTU)	62	92	18	4.5	37	73
Residue							
(non-filt. 105°C)	(mg/1)	-	140	-	-	-	89
(non-filt. 550°C)	(mg/1)	-	121	-	-	-	76
Alkalinity	(tot $CaCO_3$)	315	85	15.2	277	1322	114
Hardness	(tot $CaCO_3$)	482	164	26.2	496	2819	202
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		460	600	420	420	460	600
Data Collected	(D/M/Y)	12/04/71	28/10/71	26/02/72	15/03/72	12/04/71	28/10/71

* Composite depth ice sample

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

LAKE CLAIRE

		North West							North East	
Al	(mg/1)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/1)	<0.01	0.06	0.09	0.11	0.13	0.10	0.12	0.95	0.13
Ba	(mg/1)	0.5	0.06	0.06	0.08	0.087	0.059	0.065	0.61	0.07
Ca	(mg/1)	514	30.6	48.9	57.7	56.2	53.5	47.0	488	41.0
Cd	(mg/1)	0.0005	0.0006	<0.0005	<0.0005	<0.0005	0.010	<0.0005	0.0015	<0.0005
Co	(mg/1)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	(mg/1)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/1)	0.019	0.002	0.002	0.002	0.004	0.004	0.002	0.019	0.005
Fe	(mg/1)	0.17	0.07	0.03	0.02	0.02	<0.01	0.07	0.17	0.13
Pb	(mg/1)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/1)	0.25	0.014	0.027	0.032	0.030	0.029	0.025	0.22	0.024
Hg (total)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	0.00048	0.00064	<0.00005	0.00013	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005
Mn	(mg/1)	0.90	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	5.2	<0.015
Mg	(mg/1)	128.8	9.2	14.1	16.7	12.1	13.2	10.9	133.2	11.6
Mo	(mg/1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/1)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
K	(mg/1)	12.5	2.65	2.5	3.4	4.0	3.8	3.1	10.0	3.4
SiO_2	(mg/1)	22.0	0.8	0.7	1.1	5.1	4.2	4.7	22.2	3.2
Na	(mg/1)	536	31.0	55.9	58.8	58.0	57.0	48.0	478	53.5
Sr	(mg/1)	3.0	0.20	0.25	0.32	0.32	0.37	0.35	2.9	0.25
Tl	(mg/1)	<0.15	<0.15	<0.15	<0.15	<0.15	0.23	<0.15	<0.15	<0.15
Zn	(mg/1)	0.009	0.005	0.001	0.003	0.005	0.002	0.001	0.001	0.004
Total Cations	(me/1)	59.8885	3.7038	6.0972	6.8988	6.4261	6.3322	5.4130	56.3661	5.4213
Cl	(mg/1)	760	44.8	79.0	88.0	75.8	79.0	67.8	666	72.4
F	(mg/1)	0.59	0.12	0.15	0.16	0.17	0.20	0.20	0.55	0.10
HCO3	(mg/1)	1100.8	82.3	114.0	132.9	126.8	125.6	105.6	1016.7	99.4
N	(mg/1)	-	1.37	1.49	1.54	1.29	1.34	0.98	-	0.87
$NO_3 + NO_2$	(mg/1)	0.03	0.01	0.01	0.26	0.06	0.04	0.02	<0.01	0.02
PO4 (ortho filt)	(mg/1)	0.06	0.05	0.01	0.02	0.02	0.02	0.03	0.03	0.04
PO4 (inorg filt)	(mg/1)	0.15	0.05	0.01	0.02	0.02	0.02	0.04	0.13	0.06
PO4 (total)	(mg/1)	1.3	1.3	0.44	0.42	0.54	0.74	1.4	1.0	0.29
SO4	(mg/1)	1037	55.5	93.4	110.8	97.5	96.8	91.3	1006	74.9
Total Anions	(me/1)	61.0407	3.7709	6.0427	6.9725	6.2500	6.3066	5.5491	56.3715	5.2295
Total Diss Solids	(mg/1)	3553.3	215.3	350.9	403.3	371.6	369.7	325.1	3304.8	309.1
Total Organic C	(mg/1)	195	17	19	19	17	17	23	195	13
Total Inorg. C	(mg/1)	175	15	20	24	21	24	18	150	15
Sampling Temperature	(°C)	0	4.5	15	17.9	14.5	13.3	2.8	0	20.7
Conductivity (field)	(uohms/cm)	>2000	-	-	-	-	668	830	>2000	687
(lab)	(uohms/cm)	4980	392	620	665	599	659	500	4710	360
pH (field)		7.7	-	-	-	-	7.6	6.9	7.6	7.2
(lab)		7.9	7.4	7.8	8.0	8.1	7.7	7.8	7.9	7.9
Color		180	7	15	7	25	20	25	200	15
Turbidity	(JTU)	88	137	115	57	68	110	190	125	57
Residue										
(non-filt. 105°C)	(mg/1)	-	500	183	143	189	269	312	-	86
(non-filt. 550°C)	(mg/1)	-	447	159	107	163	244	275	-	70
Alkalinity	(tot $CaCO_3$)	903	67.5	93.5	109	104	103	86.6	834	81.5
Hardness	(tot $CaCO_3$)	1823	115	181	214	191	189	163	1776	151
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		460	520	580	620	770	710	620	460	660
Data Collected	(D/M/Y)	12/04/71	10/05/71	24/05/71	7/06/71	9/08/71	30/08/71	5/10/71	12/04/71	2/07/71

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

PRAIRIE RIVER

Al	(mg/1)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/1)	0.06	0.10	0.10	0.08	0.07	<0.01	0.11	-
Ba	(mg/1)	0.07	<0.04	0.07	0.05	0.090	<0.04	0.061	0.13
Ca	(mg/1)	38.0	42.5	43.4	36.7	38.8	43.5	48.5	-
Cd	(mg/1)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/1)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003
Cr	(mg/1)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.01
Cu	(mg/1)	0.004	0.002	0.003	0.003	0.004	0.004	0.002	0.008
Fe	(mg/1)	0.05	0.02	0.01	0.02	0.03	<0.01	0.08	0.20
Pb	(mg/1)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/1)	0.015	0.028	0.026	0.008	0.007	0.017	0.021	0.064
Hg (total)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	0.00044	0.00046	<0.00005	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/1)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.25
Mg	(mg/1)	10.1	11.9	10.9	8.0	6.9	11.1	11.9	-
Mo	(mg/1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/1)	<0.006	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.013
K	(mg/1)	2.95	2.2	3.3	1.8	1.6	2.4	3.4	-
SiO2	(mg/1)	0.8	0.7	0.9	2.6	6.5	3.8	4.1	-
Na	(mg/1)	29.0	58.0	53.0	16.2	8.3	29.6	51.5	-
Sr	(mg/1)	0.20	0.30	0.32	0.25	0.18	0.27	0.37	0.75
Tl	(mg/1)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/1)	0.004	<0.001	0.001	0.003	0.001	0.001	0.001	0.002
Total Cations	(me/1)	4.0667	5.6800	5.4527	3.2412	2.9073	4.4327	5.7305	-
Cl	(mg/1)	43.3	85.0	81.5	17.0	3.7	38.0	68.6	-
F	(mg/1)	0.11	0.12	0.15	0.11	0.09	0.15	0.20	-
HCO3	(mg/1)	96.1	96.4	101.4	111.2	136.1	135.3	113.4	-
N	(mg/1)	1.18	1.60	1.23	0.90	1.15	0.86	1.13	-
NO3 + NO2	(mg/1)	0.02	<0.01	1.6	0.25	0.04	<0.01	0.10	-
PO4 (ortho filt)	(mg/1)	0.02	0.01	0.01	0.02	0.03	0.02	0.03	-
PO4 (inorg filt)	(mg/1)	0.02	0.01	0.02	0.03	0.03	0.02	0.03	-
PO4 (total)	(mg/1)	0.60	0.51	0.33	0.38	0.51	0.39	1.1	-
SO4	(mg/1)	63.7	79.9	78.6	40.2	21.0	52.8	91.7	-
Total Anions	(me/1)	4.1251	5.6405	5.6324	3.1481	2.7779	4.3936	5.7091	-
Total Diss Solids	(mg/1)	235.4	32.78	329.0	178.5	154.1	284.0	336.2	-
Total Organic C	(mg/1)	12	22	15	12	3	12	18	-
Total Inorg. C	(mg/1)	18	18	18	16	22	24	18	15
Sampling Temperature	(°C)	8.5	19	16.8	24.0	14.5	16.8	3.3	820
Conductivity (field)	(uohms/cm)	-	-	-	357	-	501	784	-
(lab)	(uohms/cm)	431	600	372	244	274	467	580	715
pH (field)		- -	-	-	7.3	-	7.4	6.7	-
(lab)		7.4	7.4	8.0	7:6	8.2	7.9	7.7	-
Color		7	15	7	25	50	25	20	-
Turbidity	(JTU)	100	72	33	72	110	62	97	-
Residue									
(non-filt. 105°C)	(mg/1)	158	118	53	92	210	128	303	-
(non-filt. 550°C)	(mg/1)	138	106	44.8	80	188	115	266	-
Alkalinity	(tot CaCO3)	78.8	79.1	83.6	91.2	111.6	111.0	93.0	-
Hardness	(tot CaCO3)	137	156	154	125	126	155	171	-
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		58	58	0	0	40	100	172	0
Data Collected	(D/M/Y)	10/05/71	24/05/71	07/06/71	02/07/71	09/08/71	30/08/71	5/10/71	23/02/72

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACEWATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

		MAMAWI LAKE								BARIL LAKE
Al	(mg/l)	<0.10	<0.10	0.21	<0.10	<0.10	<0.10	<0.10	0.14	<0.10
B	(mg/l)	0.07	0.10	0.14	0.08	0.11	0.05	0.07	-	<0.01
Ba	(mg/l)	0.12	0.06	0.06	0.09	0.085	0.07	0.08	0.14	0.11
Ca	(mg/l)	39.1	52.8	28.3	43.5	99.9	55.6	60.3	-	72.6
Cd	(mg/l)	<0.0005	0.001	<0.0005	<0.0005	<0.0005	0.014	0.014	<0.0005	0.009
Co	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.003	0.04
Cr	(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.010
Cu	(mg/l)	0.002	0.002	0.005	0.005	0.002	0.003	0.003	0.005	0.002
Fe	(mg/l)	0.02	0.01	0.18	<0.01	0.03	<0.01	<0.01	0.86	<0.01
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/l)	0.015	0.029	0.002	0.013	0.027	0.078	0.031	0.020	0.015
Hg (total)	(mg/l)	<0.00005	<0.00005	0.0006	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005
Mn	(mg/l)	<0.015	<0.015	<0.015	0.014	<0.015	<0.015	<0.015	0.38	<0.015
Mg	(mg/l)	8.9	14.1	5.9	9.6	19.8	11.2	14.9	-	16.9
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/l)	<0.006	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.026	<0.006
K	(mg/l)	2.95	2.5	1.3	2.2	3.5	3.5	4.0	-	3.8
SiO_2	(mg/l)	1.6	0.6	3.6	4.3	3.8	5.0	5.6	-	2.7
Na	(mg/l)	26.0	57.6	4.4	22.3	52.3	53.0	60.0	-	11.6
Sr	(mg/l)	0.20	0.35	0.15	0.24	0.30	0.32	0.48	0.37	0.30
Tl	(mg/l)	<0.15	<0.15	<0.15	0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/l)	0.004	<0.001	0.004	0.003	0.001	0.001	0.001	0.005	0.001
Total Cations	(me/l)	3.8907	6.3647	2.1318	3.9867	-	6.0908	6.9469	-	5.6147
Cl	(mg/l)	36.0	88.0	1.4	26.0	71.0	75.6	81.4	-	3.1
F	(mg/l)	0.11	0.13	0.10	0.13	0.19	0.20	0.22	-	0.13
HCO_3	(mg/l)	107.3	123.1	90.0	140.2	115.8	124.3	142.6	-	176.8
N	(mg/l)	1.42	1.22	1.03	0.95	0.95	0.84	0.95	-	0.62
$NO_3 + NO_2$	(mg/l)	0.03	<0.01	0.06	<0.01	0.04	0.05	0.05	-	0.13
PO_4 (ortho filt)	(mg/l)	0.02	0.01	0.02	0.01	0.02	0.02	0.02	-	<0.01
PO_4 (inorg filt)	(mg/l)	0.03	0.01	0.03	0.02	0.03	0.03	0.03	-	<0.01
PO_4 (total)	(mg/l)	1.00	0.37	1.10	0.53	0.95	0.50	0.55	-	0.18
SO_4	(mg/l)	55.3	97.7	23.5	42.5	90.0	93.4	109.0	-	123.0
Total Anions	(me/l)	3.9290	6.5339	2.0105	3.9218	-	6.1204	6.9092	-	5.5548
Total Diss Solids	(mg/l)	222.9	374.1	113.1	219.6	397.7	359.0	405.9	-	320.9
Total Organic C	(mg/l)	15	16	8	11	14	19	21	-	15
Total Inorg. C	(mg/l)	21	22	15	26	19	16	17	-	20
Sampling Temperature	(°C)	11.8	17.2	18.4	15.8	4.4	-	-	0.5	-
Conductivity (field)	(uohms/cm)	-	-	287	357	800	-	-	380	-
(lab)	(uohms/cm)	416	670	162	403	525	616	705	-	510
pH (field)		-	-	7.1	7.2	6.4	-	-	7.6	-
(lab)		7.6	7.6	7.8	8.1	7.9	7.9	8.0	-	8.4
Color		12	8	45	27	15	20	20	-	0
Turbidity	(JTU)	118	46	78	56	160	85	98	-	39
Residue										
(non-filt. 105°C)	(mg/l)	415	74	350	115	218	130	167	-	43
(non-filt. 550°C)	(mg/l)	371	64	318	104	188	113	146	-	36
Alkalinity	(tot $CaCO_3$)	88.0	101.0	73.8	115.0	95.0	102.0	117.0	-	145
Hardness	(tot $CaCO_3$)	135	191	95.3	149	169	186	213	-	252
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	15	12.5	30	50	10	10	10	12	21
Data Collected	(D/M/Y)	10/05/71	24/05/71	02/07/71	30/08/71	05/10/71	28/10/71	28/10/71	23/02/72	28/10/71

TABLE I (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

QUATRE FOURCHES

				Below Dam	Above Dam
Al	(mg/l)	<0.08	<0.08	<0.08	<0.08
B	(mg/l)	0.08	0.03		
Ba	(mg/l)	0.08	0.069	-	-
Ca	(mg/l)	41.0	35.9	0.05	0.10
Cd	(mg/l)	0.0007	<0.0005	-	-
Co	(mg/l)	<0.002	<0.002	0.0005	0.001
Cr	(mg/l)	<0.02	<0.02	0.002	0.002
Cu	(mg/l)	0.002	0.002	<0.02	0.04
Fe	(mg/l)	0.02	0.03	0.006	0.005
Pb	(mg/l)	<0.008	<0.008	0.30	0.37
Li	(mg/l)	0.018	0.004	<0.008	<0.008
Hg (total)	(mg/l)	<0.00005	0.0005	0.020	0.031
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	<0.015	<0.015	-	-
Mg	(mg/l)	10.2	8.0	0.08	0.16
Mo	(mg/l)	<0.05	<0.05	-	-
Ni	(mg/l)	0.004	<0.006	<0.05	<0.05
K	(mg/l)	2.1	1.5	<0.006	<0.006
SiO2	(mg/l)	1.6	6.2	-	-
Na	(mg/l)	34.7	8.1	-	-
Sr	(mg/l)	0.20	0.19	-	-
Tl	(mg/l)	<0.15	<0.15	0.33	0.50
Zn	(mg/l)	0.002	<0.001	<0.15	<0.15
Total Cations	(me/l)	4.4492	2.8418	0.008	0.014
				-	-
Cl	(mg/l)	48.2	6.2	-	-
F	(mg/l)	0.12	0.08	-	-
HCO3	(mg/l)	121.9	136.5	-	-
N	(mg/l)	0.91	1.07	-	-
NO3 + NO2	(mg/l)	0.69	0.02	-	-
PO4 (ortho filt)	(mg/l)	0.01	0.01	-	-
PO4 (inorg filt)	(mg/l)	0.02	0.02	-	-
PO4 (total)	(mg/l)	0.30	0.50	-	-
SO4	(mg/l)	53.6	19.7	-	-
Total Anions	(me/l)	4.4875	2.8282	-	-
Total Diss Solids	(mg/l)	254.6	153.0	-	-
Total Organic C	(mg/l)	14	10	-	-
Total Inorg. C	(mg/l)	21	23	-	-
Sampling Temperature	(°C)	21.2	14.5	0.5	0.5
Conductivity (field)	(uohms/cm)	-	-	330	640
(lab)	(uohms/cm)	436	264	-	-
pH (field)		-	-	-	-
(lab)		8.1	7.8	7.6	7.7
Color		15	35	-	-
Turbidity	(JTU)	44	105	-	-
Residue					
(non-filt. 105°C)	(mg/l)	5	200	-	-
(non-filt. 550°C)	(mg/l)	3	178	-	-
Alkalinity	(tot $CaCO_3$)	100	112	-	-
Hardness	(tot $CaCO_3$)	145	123	-	-
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	518	470	-	-
Data Collected	(D/M/Y)	7/06/71	9/08/71	23/02/71	23/02/71

TABLE II

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

ATHABASCA RIVER AT FORT MCMURRAY

Al	(mg/1)										
B	(mg/1)										
Ba	(mg/1)										
Ca	(mg/1)	54.2	53.2	53.5	29.9	31.1	32.1	50.1	47.1	59.8	53.0
Cd	(mg/1)										
Co	(mg/1)										
Cr	(mg/1)										
Cu	(mg/1)		0.002			0.003	0.004			0.002	
Fe	(mg/1)		0.11			0.13	0.06				
Pb	(mg/1)		<0.006			0.006	<0.006			<0.006	
Li	(mg/1)										
Hg (total)	(mg/1)										
Hg (diss)	(mg/1)										
Mn	(mg/1)		<0.015			<0.015	<0.015			<0.015	
Mg	(mg/1)	13.3	14.4	14.2	7.5	6.3	5.7	11.9	11.1	6.3	10.2
Mo	(mg/1)										
Ni	(mg/1)										
K	(mg/1)	2.0	1.9	1.9	0.9	1.0	1.3	2.0	2.0	2.0	2.1
SiO2	(mg/1)	5.9	5.9	5.2	3.1	4.8	6.0	5.2	5.2	4.6	4.5
Na	(mg/1)	18.8	19.8	16.2	6.4	5.3	5.2	15.2	11.6	13.2	13.2
Sr	(mg/1)										
Tl	(mg/1)										
Zn	(mg/1)		0.004			0.011	<0.01			0.003	
Total Cations	(me/1)	4.6676	4.7550	4.5910	2.4104	2.3332	2.3332	4.1912	3.8191	4.1276	4.1117
Cl	(mg/1)	4.8	8.4	7.5	3.8	0.6	0.7	3.8	4.8	5.3	5.8
F	(mg/1)		0.11			0.08	0.09			0.11	
HCO3	(mg/1)	210.9	208.5	199.9	114.4	103.4	106.3	201.1	173.1	182.9	184.1
N	(mg/1)										
NO3 + NO2	(mg/1)	0.17	0.15	0.15	0.06	0.06	0.03	0.04	0.09	0.14	0.13
PO4 (ortho filt)	(mg/1)		0.03			0.03	0.001			0.02	
PO4 (inorg filt)	(mg/1)		0.04			0.05	0.007			0.02	
PO4 (total)	(mg/1)										
SO4	(mg/1)	43.6	45.8	48.6	21.6	24.7	19.9	34.3	37.7	41.3	41.6
Total Anions	(me/1)	4.5044	4.6168	4.5041	2.4329	2.2318	2.1827	4.1205	3.7604	4.0160	4.0503
Total Diss Solids	(mg/1)	247.2	252.9	246.3	129.8	125.1	123.5	221.8	205.2	223.3	221.7
Total Organic C	(mg/1)		13.0			24.0				10.0	
Total Inorg. C	(mg/1)		35.0			21.0				33.0	
Sampling Temperature	(°C)	21.8	23.6	24.1	24.2	24.5		21.0	21.0	23.5	26.0
Conductivity (field)	(ubhms/cm)										
(lab)	(uohms/cm)	427	429	427	244	224	211	395	373	390	396
pH (field)											
(lab)		7.8	8.0	7.9	8.1	7.9	7.8	8.3	8.0	8.2	8.1
Color		30	25	25	15	50	65	40	10	30	20
Turbidity	(JTU)	2.8	2.9	12	35	125	120	5.3	12.0	1.8	3.8
Residue											
(non-filt. 105°C)	(mg/1)					640	865	3.0			
(non-filt. 550°C)	(mg/1)					570	810	1.0			
Alkalinity	(tot $CaCO_3$)	173	171	164	93.8	84.8	87.2	165	142	150	151
Hardness	(tot $CaCO_3$)	191	193	193	106	104	104	175	164	176	175
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	335	313	1430	3670	3670	2380	601	424	349	423
Data Collected	(D/M/Y)	28/01/71	02/03/71	06/04/71	08/06/71	28/06/71	14/07/71	16/11/71	21/01/72	28/02/72	30/03/72

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

		INFLOW TO SOUTH LAKE ATHABASCA									Dunville	Crown	Richardson
		Williams River				MacFarlane River		Outlet from Davey Lake			Creek	Creek	Lake (middle)
Al	(mg/l)	<0.08	<0.08	<0.08	<0.08	<0.08	0.18	<0.08	<0.08	<0.08	<0.08	<0.08	0.88
B	(mg/l)	0.12	0.02	0.02	0.013	0.03	0.03	0.02	0.013	0.03	0.04	0.05	
Ba	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.36
Ca	(mg/l)	3.3	-	1.6	5.3	2.1	2.3	2.0	2.4	3.2	3.0	9.5	
Cd	(mg/l)	0.0005	0.001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.001
Co	(mg/l)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009
Cr	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/l)	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.013
Fe	(mg/l)	0.15	0.16	0.10	0.07	0.02	0.14	0.02	0.02	0.03	0.3	0.78	7.6
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	0.024	<0.008	<0.008	<0.008	<0.008	<0.008	0.007
Li	(mg/l)	0.001	<0.003	<0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	0.030
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00008
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Mn	(mg/l)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.044	5.7
Mg	(mg/l)	1.1	-	0.1	-	0.5	0.7	0.8	0.8	0.8	0.8	2.4	
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/l)	0.003	<0.05	<0.004	<0.004	<0.05	<0.05	<0.05	<0.004	<0.004	0.006	<0.06	0.017
K	(mg/l)	0.3	0.5	0.1	0.7	0.5	0.5	0.5	0.5	0.5	0.3	1.3	
SiO_2	(mg/l)	1.0	4.5	4.6	5.6	5.7	5.1	5.8	5.8	4.0	10.0	6.0	
Na	(mg/l)	1.1	1.4	0.4	1.6	1.3	1.4	1.2	1.4	1.4	1.4	2.1	
Sr	(mg/l)	0.05	0.04	0.05	0.04	0.05	0.04	0.03	0.04	0.05	0.03	0.1	0.70
Tl	(mg/l)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/l)	0.003	0.003	0.002	0.003	<0.001	<0.004	0.001	0.002	<0.004	0.003	0.006	0.020
Total Cations	(me/l)	0.3187	-	0.1134	0.4380	0.2163	0.2536	0.2317	0.2603	0.3008	0.3002	0.8380	
Cl	(mg/l)	3.6	3.9	1.1	4.0	2.8	3.5	3.0	3.6	0.9	1.5	8.5	
F	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
HCO_3	(mg/l)	9.0	-	3.1	14.8	5.3	6.2	5.6	6.2	6.8	12.9	40.7	
N	(mg/l)	0.25	0.20	0.72	0.21	0.43	0.15	0.39	0.03	0.30	0.11	0.65	
NO_3 + NO_2	(mg/l)	1.2	0.05	<0.01	0.04	0.01	0.01	<0.01	0.02	<0.01	0.02	0.01	
PO_4 (ortho filt)	(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	
PO_4 (inorg filt)	(mg/l)	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.05	
PO_4 (total)	(mg/l)	0.04	0.03	0.02	0.01	0.03	0.05	0.03	0.05	0.01	0.06	0.13	
SO_4	(mg/l)	0.8	1.1	0.2	2.3	0.5	1.4	0.8	0.3	3.9	0.9	0.8	
Total Anions	(me/l)	0.2851	-	0.0951	0.4029	0.1752	0.2296	0.1929	0.2097	0.2185	0.2731	0.9260	
Total Diss Solids	(mg/l)	21.0	-	9.9	28.0	16.0	18.0	16.9	18.0	18.1	24.4	50.8	
Total Organic C	(mg/l)	7	6	8	7	3	5	3	9	9	8	11	
Total Inorg. C	(mg/l)	2	2	<2	5	<2	2	<2	<2	<2	3	4	
Sampling Temperature	(°C)	10.1	11.2	-	6.8	-	8.5	-	7.8	5.8	7.9	1.1	0.5
Conductivity (field)	(uohms/cm)	-	-	-	72	-	-	-	-	36	-	132	860
(lab)	(uohms/cm)	41.0	37.5	26.2	45.1	27.0	29.0	29.1	31.0	35.1	35.1	100	
pH (field)		-	-	-	6.1	-	-	-	-	6.1	-	6.8	7.5
(lab)		6.9	-	6.7	7.2	6.8	6.9	6.7	6.8	6.4	7.0	7.1	
Color		15	25	5	20	5	15	5	10	5	35	65	
Turbidity	(JTU)	3.6	4.6	1.2	2.6	2.2	4.3	2.6	1.1	2.4	1.7	5.7	
Residue													
(non-filt. 105°C)	(mg/l)	5.6	2.4	-	-	-	1.2	-	-	-	-	-	
(non-filt. 550°C)	(mg/l)	3.8	<0.2	-	-	-	<0.2	-	-	-	-	-	
Alkalinity	(tot $CaCO_3$)	7.4	-	3.0	12.1	4.3	5.1	4.6	5.1	5.6	10.6	33.4	
Hardness	(tot $CaCO_3$)	12.9	-	4.3	17.2	7.5	8.5	8.4	9.2	11.2	11.5	41.8	
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		-	-	-	-	-	-	-	-	-	-	-	
Data Collected	(D/M/Y)	7/6/71	27/7/71	9/09/71	9/10/71	9/6/71	27/7/71	10/6/71	9/9/71	9/10/71	7/6/71	26/04/71	22/02/72

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

MAYBELLE RIVER

Al	(mg/l)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/l)	0.03	0.02	0.02	1.6	0.03	0.02	0.02	0.04
Ba	(mg/l)	0.07	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05
Ca	(mg/l)	7.7	7.3	8.0	9.3	10.1	12.0	11.3	10.6
Cd	(mg/l)	<0.0005	<0.0005	0.001	0.001	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	(mg/l)	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001
Fe	(mg/l)	0.46	0.29	0.24	0.14	0.26	0.09	0.25	0.08
Pb	(mg/l)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Li	(mg/l)	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003	0.002
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Mg	(mg/l)	2.7	2.4	2.6	2.7	3.0	2.8	3.3	3.2
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/l)	<0.06	<0.06	<0.06	0.06	<0.06	<0.06	<0.06	<0.06
K	(mg/l)	0.7	0.9	0.7	0.6	0.8	0.6	0.7	0.6
SiO2	(mg/l)	9.3	9.0	9.6	9.1	8.2	9.9	8.9	9.9
Na	(mg/l)	1.2	1.0	1.4	1.3	1.6	1.4	1.9	1.5
Sr	(mg/l)	0.05	0.05	<0.05	0.05	0.05	0.07	0.05	0.15
Ti	(mg/l)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/l)	0.003	0.004	0.001	0.004	0.003	0.001	0.002	<0.001
Total Cations	(me/l)	0.7012	0.6438	0.7048	0.7656	0.8548	0.9102	0.9493	0.8771
Cl	(mg/l)	1.5	0.6	1.7	2.7	1.4	1.5	2.5	1.7
F	(mg/l)	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	0.06	<0.05
HCO3	(mg/l)	35.4	33.0	37.4	41.0	44.4	49.6	40.8	47.3
N	(mg/l)	0.28	0.31	0.34	0.7	0.23	0.26	0.39	0.15
$NO_3 + NO_2$	(mg/l)	0.05	0.01	<0.01	0.01	0.01	0.02	<0.01	0.02
PO4 (ortho filt)	(mg/l)	0.01	0.02	<0.01	0.01	0.02	<0.01	0.01	0.01
PO4 (inorg filt)	(mg/l)	0.02	0.02	0.01	0.01	0.03	0.01	0.02	0.01
PO4 (total)	(mg/l)	0.08	0.08	0.06	0.07	0.05	0.05	0.07	0.06
SO4	(mg/l)	1.1	1.0	1.0	1.1	0.8	0.2	7.2	0.6
Total Anions	(me/l)	0.6456	0.5796	0.6824	0.7733	0.7839	0.8603	0.8931	0.8363
Total Diss Solids	(mg/l)	41.8	38.5	43.4	47.1	47.8	52.9	56.0	51.5
Total Organic C	(mg/l)	7	7	9	8	7	7	6	5
Total Inorg. C	(mg/l)	3	6	5	7	8	9	9	7
Sampling Temperature	(°C)	0.6	7.2	14.5	18.0	18.5	18.2	9.0	2.8
Conductivity (field)	(uohms/cm)	108				200		125	100
(lab)	(uohms/cm)	69	67	70	80	81	87	91	82
pH (field)		6.4				7.2		8.2	7.3
(lab)		7.3	7.1	7.5	7.5	7.7	7.4	7.4	7.3
Color		35	35	28	25	30	30	30	20
Turbidity	(JTU)	6.0	4.7	2.5	2.9	4.8	2.3	3.7	3.0
Residue									
(non-filt. 105°C)	(mg/l)		12.0			2.4		3.6	
(non-filt. 550°C)	(mg/l)		5.0			0.4		1.6	
Alkalinity	(tot $CaCO_3$)	29.0	27.1	30.7	33.6	36.4	40.7	33.5	38.8
Hardness	(tot $CaCO_3$)	30.4	28.2	31.0	34.6	37.7	41.6	42.0	39.7
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		-	-	-	-	-	-	-	-
Data Collected	(D/M/Y)	26/04/71	10/5/71	24/5/71	07/06/71	07/07/71	09/08/71	30/08/71	05/10/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

INFLOW TO SOUTH LAKE ATHABASCA

Harrison Creek

Al	(mg/1)	0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/1)	0.06	0.05	0.07	0.05	0.06	0.05	0.05	0.05
Ba	(mg/1)	0.13	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	(mg/1)	4.3	5.3	7.1	8.7	-	14.3	14.4	11.4
Cd	(mg/1)	<0.0005	0.0005	<0.0005	0.001	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/1)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	(mg/1)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.019	<0.02
Cu	(mg/1)	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Fe	(mg/1)	1.2	0.97	0.61	0.87	0.92	0.02	1.2	0.07
Pb	(mg/1)	<0.008	<0.008	<0.008	0.008	-	<0.008	<0.008	<0.008
Li	(mg/1)	<0.003	<0.003	0.003	0.004	0.004	0.003	0.005	0.006
Hg (total)	(mg/1)	<0.00005	0.00005	<0.00005	<0.00005	<0.00005	0.00021	0.00030	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0010	0.00007	<0.0005
Mn	(mg/1)	0.15	0.43	0.028	<0.013	<0.015	0.014	<0.014	<0.015
Mg	(mg/1)	2.5	2.8	3.2	3.8	-	5.7	5.7	4.9
Mo	(mg/1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/1)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
K	(mg/1)	1.4	0.7	0.9	0.9	1.0	0.5	0.7	0.8
SiO_2	(mg/1)	4.5	5.1	4.5	5.6	9.0	9.4	11.2	10.2
Na	(mg/1)	1.2	1.6	2.0	1.8	2.8	2.3	2.3	2.6
Sr	(mg/1)	0.05	0.05	0.05	0.03	0.1	0.1	0.1	0.1
Tl	(mg/1)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/1)	0.006	0.004	0.001	0.006	-	0.001	0.002	0.002
Total Cations	(me/1)	0.5721	0.6344	0.7603	0.8948	-	1.2964	1.3699	1.1093
Cl	(mg/1)	3.2	7.8	5.8	5.7	5.2	8.8	9.1	8.9
F	(mg/1)	<0.05	0.05	0.07	0.06	0.07	0.06	0.07	0.06
HCO3	(mg/1)	24.5	24.1	34.9	41.5	-	58.9	59.4	45.1
N	(mg/1)	0.82	0.47	0.42	0.95	0.98	0.49	1.24	0.48
NO_3 + NO_2	(mg/1)	0.02	<0.01	<0.01	0.03	0.01	0.02	0.01	0.01
PO4 (ortho filt)	(mg/1)	0.02	0.04	0.02	0.02	0.02	0.01	<0.01	<0.01
PO4 (inorg filt)	(mg/1)	0.05	0.05	0.03	0.03	0.05	0.03	0.03	<0.01
PO4 (total)	(mg/1)	0.29	0.15	0.12	-	0.16	0.08	0.20	0.10
SO4	(mg/1)	1.4	1.0	1.5	0.9	1.0	0.6	6.6	0.2
Total Anions	(me/1)	0.5212	0.6385	0.7700	0.8623	-	1.2289	1.3706	0.9972
Total Diss Solids	(mg/1)	30.7	36.2	42.3	48.0	-	70.8	79.4	61.3
Total Organic C	(mg/1)	13	14	15	13	12	10	13	9
Total Inorg. C	(mg/1)	2	6	5	6	9	9	10	7
Sampling Temperature	(°C)	1.1	7.8	14.5	20.0	21.2	14.5	7.2	3.3
Conductivity (field)	(uohms/cm)	50	-	-	-	125	-	217	86
(lab)	(uohms/cm)	48.2	106	72	82	184	126	135	108
pH (field)		7.2	-	-	-	7.4	-	7.7	6.7
(lab)		7.0	6.8	7.3	7.6	-	7.5	7.5	7.6
Color		-	70	83	90	20	60	75	35
Turbidity	(JTU)	24	15	13	6.9	2.6	5.2	11.0	5.3
Residue									
(non-filt. 105°C)	(mg/1)	-	22.0	11.6	45.6	11.8	2.0	21.6	12.6
(non-filt. 550°C)	(mg/1)	-	12.0	4.4	2.4	5.8	<0.2	15.8	5.8
Alkalinity	(tot $CaCO_3$)	20.1	19.8	28.6	34.0	-	48.3	48.7	37.0
Hardness	(tot $CaCO_3$)	21.2	24.9	31.2	37.6	-	59.3	59.8	48.7
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		-	-	-	-	-	-	-	-
Data Collected	(D/M/Y)	26/04/71	10/05/71	24/05/71	1/06/71	7/07/71	9/08/71	30/08/71	4/10/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

INFLOW TO SOUTH LAKE ATHABASCA

Old Fort Creek

Al	(mg/l)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/l)	0.05	0.03	0.04	0.03	0.05	0.04	0.03	0.05
Ba	(mg/l)	0.16	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	(mg/l)	8.2	13.8	13.8	14.9	16.4	15.0	17.1	14.4
Cd	(mg/l)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/l)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/l)	<0.001	0.007	<0.001	0.001	<0.001	0.001	<0.001	<0.001
Fe	(mg/l)	0.42	0.16	0.17	0.14	0.11	0.04	0.17	0.07
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/l)	<0.003	0.003	0.003	0.005	0.004	0.005	0.004	0.005
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	0.038	<0.015	<0.015	<0.015	<0.015	<0.015	<0.014	<0.015
Mg	(mg/l)	3.1	6.7	6.6	6.9	7.4	6.4	6.4	6.2
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/l)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
K	(mg/l)	0.9	2.3	0.9	1.1	1.2	0.7	0.9	0.9
SiO_2	(mg/l)	5.5	6.9	6.3	6.4	6.2	7.5	7.0	8.3
Na	(mg/l)	1.6	2.4	3.3	3.6	4.6	3.3	3.6	3.3
Sr	(mg/l)	0.1	0.15	0.15	0.15	0.30	0.21	0.26	0.20
Tl	(mg/l)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/l)	0.004	0.002	0.002	0.005	0.003	<0.001	0.002	0.002
Total Cations	(me/l)	0.7795	1.4116	1.4072	1.5034	1.6638	1.4386	1.5685	1.3989
Cl	(mg/l)	9.6	16.7	22.4	26.0	28.4	22.0	27.0	22.8
F	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
HCO_3	(mg/l)	26.1	51.2	45.2	45.2	51.5	40.1	43.4	42.8
N	(mg/l)	0.62	0.26	0.11	0.56	0.34	0.30	0.16	0.20
$NO_3 + NO_2$	(mg/l)	0.03	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
PO_4 (ortho filt)	(mg/l)	<0.01	0.01	<0.01	0.01	0.02	<0.01	<0.01	<0.01
PO_4 (inorg filt)	(mg/l)	0.01	0.01	0.01	0.01	0.03	<0.01	<0.01	<0.01
PO_4 (total)	(mg/l)	0.18	0.06	0.04	-	0.05	0.02	0.03	0.04
SO_4	(mg/l)	1.3	2.0	0.5	1.7	1.1	3.6	2.7	0.6
Total Anions	(me/l)	0.7252	1.3506	1.3816	1.5217	1.6701	1.3512	1.5267	1.3549
Total Diss Solids	(mg/l)	43.2	76.0	76.1	83.3	92.2	78.4	86.1	77.6
Total Organic C	(mg/l)	11	7	8	6	7	7	6	4
Total Inorg. C	(mg/l)	2	9	7	8	7	7	8	8
Sampling Temperature	(°C)	0.6	7.8	15.0	20.2	21.2	15.8	9.0	3.3
Conductivity (field)	(ubhms/cm)	126	-	-	-	195	-	213	1160
(lab)	(uohms/cm)	83	155	152	168	183	171	178	151
pH (field)		7.0	-	-	-	7.3	-	7.8	6.6
(lab)		7.3	7.5	7.4	7.9	7.3	7.6	7.6	7.7
Color		55	35	30	20	20	25	20	20
Turbidity	(JTU)	17	4.7	2.4	2.1	2.6	1.9	2.1	2.4
Residue									
(non-filt. 105°C)	(mg/l)	-	12.0	-	-	-	-	-	-
(non-filt. 550°C)	(mg/l)	-	2.0	-	-	-	-	-	-
Alkalinity	(tot $CaCO_3$)	21.4	42.0	37.1	37.8	42.2	32.9	35.6	35.1
Hardness	(tot $CaCO_3$)	33.4	62.4	62.0	65.9	71.7	64.0	69.4	61.9
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		-	-	-	-	-	-	-	-
Data Collected	(D/M/Y)	26/04/71	10/05/71	24/05/71	1/06/71	7/07/71	9/08/71	30/08/71	4/10/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACEWATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

INFLOW TO EAST LAKE ATHABASCA

		Outlet of Black Lake			Fond du Lac River			Morris Creek
Al	(mg/l)	<0.05	<0.06	<0.06	<0.1	<0.06	<0.06	<0.05
B	(mg/l)	<0.01	0.03	0.008	0.02	0.02	<0.01	0.03
Ba	(mg/l)	<0.04	<0.03	<0.03	<0.05	<0.03	<0.03	<0.04
Ca	(mg/l)	2.9	2.5	2.4	2.9	3.5	3.8	9.8
Cd	(mg/l)	<0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.008
Co	(mg/l)	<0.05	<0.002	<0.002	<0.05	<0.002	<0.002	<0.05
Cr	(mg/l)	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02
Cu	(mg/l)	<0.001	<0.001	0.002	<0.001	<0.001	0.010	<0.001
Fe	(mg/l)	0.01	0.01	<0.01	0.01	<0.01	0.07	0.05
Pb	(mg/l)	<0.004	<0.006	<0.006	<0.005	<0.006	<0.006	<0.004
Li	(mg/l)	<0.002	0.001	0.001	<0.002	<0.001	0.002	<0.002
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	<0.015	<0.014	<0.012	<0.015	<0.014	<0.012	0.015
Mg	(mg/l)	1.0	0.7	0.9	0.9	0.4	1.4	2.7
Mo	(mg/l)	<0.05	<0.05	<0.05	<0.06	<0.05	<0.05	<0.05
Ni	(mg/l)	<0.05	<0.004	<0.004	<0.05	<0.004	<0.004	<0.05
K	(mg/l)	0.6	0.4	1.5	0.6	0.5	0.7	1.0
SiO_2	(mg/l)	4.0	3.9	4.7	3.2	3.8	4.8	4.8
Na	(mg/l)	1.5	0.9	1.0	1.4	1.1	1.3	2.3
Sr	(mg/l)	0.04	0.03	0.04	<0.03	0.03	0.03	0.08
Tl	(mg/l)	<0.10	<0.15	<0.15	<0.15	<0.15	<0.15	<0.10
Zn	(mg/l)	<0.001	0.002	0.003	0.005	0.001	0.008	<0.001
Total Cations	(me/l)	0.3081	0.2323	0.2757	0.2955	0.2682	0.3830	0.8294
Cl	(mg/l)	2.3	2.0	1.6	1.8	2.3	2.5	2.2
F	(mg/l)	0.05	<0.05	0.06	0.05	<0.05	0.06	0.12
HCO3	(mg/l)	11.6	7.9	9.4	11.4	9.8	12.9	41.5
N	(mg/l)	0.41	<0.01	0.05	0.18	<0.01	<0.01	0.67
$NO_3 + NO_2$	(mg/l)	<0.01	0.02	<0.01	<0.01	0.01	0.02	<0.01
PO4 (ortho filt)	(mg/l)	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01
PO4 (inorg filt)	(mg/l)	<0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01
PO4 (total)	(mg/l)	0.03	0.03	0.01	0.03	0.02	0.01	0.04
SO4	(mg/l)	0.8	0.2	1.0	1.8	0.7	1.8	0.9
Total Anions	(me/l)	0.2739	0.1906	0.2229	0.2806	0.2393	0.3231	0.7666
Total Diss Solids	(mg/l)	18.9	14.6	17.8	18.4	17.2	22.8	44.2
Total Organic C	(mg/l)	4	6	6	5	6	8	10
Total Inorg. C	(mg/l)	<2	3	3	2	<2	2	6
Sampling Temperature	(°C)	-	7.8	8.3	17.8	7.2	7.8	-
Conductivity (field)	(uohms/cm)	-	-	38.5	-	-	43.8	-
(lab)	(uohms/cm)	36.5	21.0	34.0	33.9	37.9	40.0	83
pH (field)		-	-	6.1	-	-	6.2	-
(lab)		7.1	7.1	6.7	6.7	7.1	6.8	7.5
Color		5	10	5	7	5	5	20
Turbidity	(JTU)	2.0	0.9	0.9	2.0	0.8	1.1	2.2
Residue								
(non-filt. 105°C)	(mg/l)	-	-	-	-	-	-	-
(non-filt. 550°C)	(mg/l)	-	-	-	-	-	-	-
Alkalinity	(tot $CaCO_3$)	9.5	6.5	7.7	9.5	8.0	10.6	34
Hardness	(tot $CaCO_3$)	11.3	9.3	9.6	11.0	10.3	15.2	35.6
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		-	-	-	-	-	-	-
Data Collected	(D/M/Y)	20/06/71	9/09/71	9/10/71	27/07/71	9/09/71	9/10/71	19/06/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

LAKE ATHABASCA

				West				North West		
Al	(mg/l)	<0.08	<0.08	0.12	0.28	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/l)	0.03	0.04	-	0.05	0.04	0.03	0.04	0.02	<0.01
Ba	(mg/l)	<0.04	<0.04	0.06	0.05	<0.04	<0.04	<0.04	<0.04	0.10
Ca	(mg/l)	14.3	16.0	-	37.9	14.1	11.6	13.5	8.8	38.8
Cd	(mg/l)	0.0005	0.0007	0.003	0.011	<0.0005	<0.0005	<0.0005	<0.0005	0.009
Co	(mg/l)	<0.002	<0.002	0.003	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	(mg/l)	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/l)	0.001	0.001	0.006	0.009	0.001	0.001	0.001	<0.001	0.001
Fe	(mg/l)	0.02	0.15	0.61	0.41	0.01	0.02	0.02	<0.01	0.06
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/l)	0.004	0.007	0.011	0.009	0.004	0.005	0.004	<0.003	0.008
Hg (total)	(mg/l)	<0.00005	<0.00005	0.00007	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	-	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	0.015	<0.015	0.06	0.025	<0.015	0.02	<0.015	<0.015	<0.016
Mg	(mg/l)	3.6	11.1	-	7.2	3.9	3.0	3.4	2.0	8.4
Mo	(mg/l)	<0.06	<0.06	<0.05	-	<0.06	<0.06	<0.06	<0.05	<0.05
Ni	(mg/l)	<0.06	<0.06	0.042	0.005	<0.06	<0.06	<0.06	<0.05	<0.05
K	(mg/l)	1.1	1.2	-	1.6	1.3	1.0	1.0	0.9	1.3
SiO_2	(mg/l)	11.3	4.0	-	6.2	4.2	3.5	3.7	2.8	5.2
Na	(mg/l)	3.9	5.8	-	17.9	3.4	3.5	3.5	2.7	15.0
Sr	(mg/l)	0.10	0.30	0.31	0.20	0.10	0.05	0.10	0.07	0.21
Tl	(mg/l)	<0.2	<0.2	<0.15	<0.15	<0.2	<0.2	<0.2	<0.10	<0.15
Zn	(mg/l)	0.005	0.003	0.002	0.007	0.005	0.004	0.003	0.001	0.001
Total Cations	(me/l)	1.2086	2.0025	-	3.3251	1.2061	1.0045	1.1322	0.7441	3.3161
Cl	(mg/l)	4.6	4.3	-	24.5	5.1	4.3	4.3	3.2	16.6
F	(mg/l)	0.06	<0.05	-	-	0.08	0.06	0.06	0.05	0.10
HCO_3	(mg/l)	55.1	108.0	-	131.7	56.7	43.8	51.8	32.9	146.3
N	(mg/l)	0.21	0.16	-	0.16	0.15	0.15	0.11	0.23	0.44
$NO_3 + NO_2$	(mg/l)	0.08	0.18	-	-	0.08	0.05	-	0.02	0.04
PO_4 (ortho filt)	(mg/l)	0.01	0.02	-	0.015	0.01	0.01	0.02	<0.01	0.01
PO_4 (inorg filt)	(mg/l)	0.02	0.02	-	0.016	0.02	0.01	0.02	<0.01	0.01
PO_4 (total)	(mg/l)	0.03	0.05	-	0.092	0.07	0.02	0.09	0.03	0.20
SO_4	(mg/l)	7.3	2.1	-	25.0	7.4	6.6	6.9	4.9	25.2
Total Anions	(me/l)	1.1894	1.9387	-	3.3683	1.2326	0.9800	1.1177	0.7347	3.3963
Total Diss Solids	(mg/l)	73.7	98.5	-	185.9	67.8	55.3	62.0	41.7	182.8
Total Organic C	(mg/l)	6	5	-	8	6	6	6	3	14
Total Inorg. C	(mg/l)	12	14	-	17	10	10	10	5	18
Sampling Temperature	(°C)	0	0	0.5	0.3	0	0	0	-	-
Conductivity (field)	(uohms/cm)	136.5	254.8	195	-	109.2	118.3	154.7	-	-
(lab)	(uohms/cm)	121	257	-	340	126	102	115	80	327
pH (field)		7.9	7.4	7.1	7.1	7.4	8.1	7.8	-	-
(lab)		7.7	7.3	-	8.2	7.8	7.7	7.7	7.8	8.2
Color		5	20	-	15	10	5	7	0	10
Turbidity	(JTU)	2.9	10	-	2.5	17	2.8	17	-	46.4
Residue										
(non-filt. 105°C)	(mg/l)	-	15.2	-	-	2.4	-	52	-	36.0
(non-filt. 550°C)	(mg/l)	-	8	-	-	<0.2	-	44	1.8	37
Alkalinity	(tot $CaCO_3$)	45.2	58.6	-	108	46.5	35.9	42.5	27.0	120
Hardness	(tot $CaCO_3$)	50.6	106.0	-	125	51.5	41.5	48.0	30.5	132
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	180000	180000	175000	-	180000	180000	180000	197000	192500
Data Collected	(D/M/Y)	5/04/71	5/04/71	21/02/72	16/03/72	31/03/71	5/04/71	5/04/71	19/06/71	28/10/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACEWATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

LAKE ATHABASCA

					Middle					East	
Al	(mg/l)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/l)	0.03	0.02	0.03	<0.01	0.03	<0.01	-	-	0.01	<0.01
Ba	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ca	(mg/l)	11.1	9.2	7.2	8.2	8.1	11.2	-	3.4	3.4	11.6
Cd	(mg/l)	<0.0005	<0.0005	0.002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/l)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
Cr	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	(mg/l)	0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001
Fe	(mg/l)	0.02	0.01	0.01	0.02	<0.01	<0.04	0.27	0.01	0.01	0.04
Pb	(mg/l)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/l)	<0.004	<0.003	0.004	0.003	<0.003	<0.003	0.004	<0.003	<0.003	0.004
Hg (total)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/l)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005
Mn	(mg/l)	<0.015	<0.015	<0.015	<0.012	<0.014	<0.016	0.03	<0.015	<0.015	<0.016
Mg	(mg/l)	3.4	2.0	2.1	2.3	2.1	2.3	-	1.4	1.2	2.2
Mo	(mg/l)	<0.06	<0.05	<0.06	<0.05	<0.05	<0.05	<0.04	<0.06	<0.06	<0.05
Ni	(mg/l)	<0.06	<0.05	<0.05	<0.004	<0.004	<0.05	-	<0.05	<0.05	<0.05
K	(mg/l)	0.9	0.9	1.0	0.8	0.8	0.9	-	-	0.7	0.9
SiO_2	(mg/l)	3.6	2.6	2.8	2.8	2.8	3.0	-	-	3.8	2.7
Na	(mg/l)	3.4	3.1	2.9	2.1	2.8	3.0	-	-	1.7	2.7
Sr	(mg/l)	0.05	0.10	0.04	0.07	0.06	0.06	0.08	0.05	0.04	0.07
Ti	(mg/l)	<0.2	<0.10	<0.15	<0.15	<0.15	<0.15	<0.15	<0.10	<0.15	<0.15
Zn	(mg/l)	0.003	0.001	0.011	0.004	0.001	0.001	0.002	<0.001	0.011	0.003
Total Cations	(me/l)	1.0056	0.7820	0.6843	0.7113	0.7192	0.9016	-	-	0.3608	0.9024
Cl	(mg/l)	4.0	3.5	3.5	2.7	3.2	3.5	-	3.4	3.4	3.4
F	(mg/l)	0.06	0.06	0.04	0.06	0.05	0.07	-	<0.05	0.05	0.08
HCO3	(mg/l)	45.4	30.5	29.1	32.1	31.0	40.5	-	-	13.7	39.7
N	(mg/l)	<0.01	0.36	0.30	<0.01	<0.01	0.28	-	0.48	0.20	0.20
NO3 + NO2	(mg/l)	0.17	0.02	<0.01	0.02	0.11	0.05	-	0.02	<0.01	0.05
PO4 (ortho filt)	(mg/l)	0.01	<0.01	0.01	<0.01	<0.01	<0.01	-	<0.01	0.01	<0.01
PO4 (inorg filt)	(mg/l)	0.02	<0.01	0.01	<0.01	0.01	<0.01	-	<0.01	0.01	<0.01
PO4 (total)	(mg/l)	0.06	0.03	0.03	<0.01	0.02	0.14	-	0.03	0.03	0.35
SO4	(mg/l)	7.6	5.5	5.1	5.1	5.2	6.1	-	0.6	1.1	5.6
Total Anions	(me/l)	1.0203	0.7162	0.6852	0.7114	0.7104	0.8936	-	-	0.3450	0.8689
Total Diss Solids	(mg/l)	57.2	42.0	39.1	40.0	40.8	50.2	-	-	22.1	49.0
Total Organic C	(mg/l)	5	4	5	7	5	8	-	3	5	7
Total Inorg. C	(mg/l)	8	5	5	4	6	5	-	<2	3	12
Sampling Temperature	(°C)	0	-	17.8	8.3	7.2	-	-	-	17.8	-
Conductivity (field)	(uohms/cm)	100.1	-	-	93.0	-	-	-	-	-	-
(lab)	(uohms/cm)	102	79	72.0	74.0	74.0	91.0	102	43.9	41.7	90
pH (field)		7.1	-	-	6.2	-	-	-	-	-	-
(lab)		7.9	6.8	7.0	7.4	7.6	7.8	7.4	6.9	6.8	7.8
Color		10	0	7	5	5	0	-	5	5	0
Turbidity	(JTU)	12	5.0	1.8	1.3	2.8	43.0	-	2.6	-	146
Residue											
(non-filt. 105°C)	(mg/l)	2.8	2.4	-	-	-	38	-	1.4	-	130
(non-filt. 550°C)	(mg/l)	0.8	3.7	-	-	-	28	-	3.4	2.4	77.0
Alkalinity	(tot $CaCO_3$)	37.2	25.0	23.9	26.3	25.4	33.2	-	8.6	11.2	32.6
Hardness	(tot $CaCO_3$)	41.8	31.5	26.8	30.1	28.9	37.6	-	14.4	13.4	38.2
Discharge per month (1000 Ac.Ft.) (or Lake Volume)		180000	197000	201500	194000	194000	192500	175000	197000	201500	192500
Data Collected	(D/M/Y)	31/03/71	19/06/71	27/07/71	9/10/71	9/10/71	28/10/71	22/02/72	20/06/71	27/07/71	28/10/71

TABLE II (Cont'd)

CHEMICAL AND PHYSICAL PROPERTIES OF THE SURFACE WATERS OF THE ATHABASKA DELTA COMPLEX, ALBERTA

RIVIERE DES ROCHERS

Al	(mg/1)	<0.08	<0.08	<0.08	0.15	<0.08	<0.08	<0.08	<0.08	<0.08
B	(mg/1)	0.05	0.04	0.04	0.10	0.06	0.04	0.03	<0.01	-
Ba	(mg/1)	0.05	<0.04	0.08	<0.04	0.07	0.097	<0.04	0.05	<0.04
Ca	(mg/1)	26.2	23.7	25.2	26.9	31.0	22.9	14.5	14.9	-
Cd	(mg/1)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Co	(mg/1)	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Cr	(mg/1)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03
Cu	(mg/1)	0.005	0.002	0.002	0.002	0.003	0.003	<0.001	0.001	0.006
Fe	(mg/1)	0.09	0.09	0.04	0.11	0.05	0.01	0.02	<0.04	0.17
Pb	(mg/1)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/1)	0.005	0.005	0.005	0.004	0.005	0.003	0.004	0.004	0.006
Hg (total)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	0.00023	0.00021	<0.00005	<0.00005	<0.00005
Hg (diss)	(mg/1)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Mn	(mg/1)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.02
Mg	(mg/1)	4.9	5.1	6.1	5.2	6.8	4.9	2.9	3.1	-
Mo	(mg/1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/1)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
K	(mg/1)	2.0	1.4	1.2	1.1	1.3	1.1	0.8	1.2	-
SiO2	(mg/1)	4.0	3.8	3.4	4.4	6.4	3.9	3.0	3.1	-
Na	(mg/1)	7.0	7.1	8.9	6.5	7.6	6.4	4.3	4.3	-
Sr	(mg/1)	0.10	0.10	0.13	0.15	0.16	0.15	0.12	0.07	0.14
Tl	(mg/1)	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/1)	0.004	<0.001	0.002	0.004	0.001	0.002	<0.001	0.001	0.013
Total Cations	(me/1)	2.0709	1.9516	2.1793	2.0869	2.4728	1.8529	1.1707	1.2163	-
Cl	(mg/1)	4.2	5.6	7.0	4.4	4.5	5.2	4.8	4.7	-
F	(mg/1)	0.07	0.07	0.08	0.08	0.08	0.08	0.06	0.07	-
HCO3	(mg/1)	90.6	91.6	93.3	93.8	118.3	90.9	53.8	53.9	-
N	(mg/1)	0.78	1.39	0.70	0.62	0.85	0.56	0.16	0.30	-
NO_3 + NO2	(mg/1)	0.08	0.01	2.9	0.06	0.10	0.01	0.02	0.07	-
PO4 (ortho filt)	(mg/1)	0.03	0.02	0.02	0.02	0.01	0.01	-	<0.01	-
PO4 (inorg filt)	(mg/1)	0.03	0.02	0.03	0.03	0.01	0.01	-	<0.01	-
PO4 (total)	(mg/1)	0.75	0.30	0.43	0.21	0.28	0.26	0.16	0.23	-
SO4	(mg/1)	17.7	14.2	20.4	16.4	16.6	11.8	7.9	8.5	-
Total Anions	(me/1)	1.9771	1.9584	2.2020	2.0078	2.4172	1.8877	1.1846	1.1976	-
Total Diss Solids	(mg/1)	111.1	106.1	131.1	111.4	133.0	101.1	64.8	66.7	-
Total Organic C	(mg/1)	14	16	14	13	15	6	6	9	-
Total Inorg. C	(mg/1)	16	17	18	12	19	17	6	6	-
Sampling Temperature	(°C)	9.0	11.9	16.8	18.4	15.6	14.5	3.3	-	0.5
Conductivity (field)	(uohms/cm)	-	-	-	282	-	187.5	144.0	-	100
(lab)	(uohms/cm)	195	190	245	174	228	186	129	122	-
pH (field)		-	-	-	7.2	-	6.8	6.2	-	7.4
(lab)		7.5	7.8	8.0	7.8	8.2	8.1	7.6	7.8	-
Color		35	35	25	30	40	10	7	0	-
Turbidity	(JTU)	99	58	54	37	54	46	23	38	-
Residue										
(non-filt. 105°C)	(mg/1)	252	134	129	77	88	56	47	80	-
(non-filt. 550°C)	(mg/1)	228	122	114	68	72	51	37	72	-
Alkalinity	(tot $CaCO_3$)	74.3	75.1	76.5	76.9	97.0	74.6	44.1	44.2	-
Hardness	(tot $CaCO_3$)	85.9	80.4	88.6	89.1	106	77.8	48.5	50.3	-
Discharge per month (or Lake Volume)	(1000 Ac.Ft.)	approx. 2000	approx. 2000	3356	3345	5294	5294	approx. 3615	3615	-
Data Collected	(D/M/Y)	10/05/71	24/05/71	7/06/71	2/07/71	9/08/71	30/08/71	5/10/71	28/10/71	23/02/71

APPENDIX B

TABLE I

ON-SITE WATER QUALITY ANALYSIS

Traverse Line No.	Stn. No.	Date 1971	Ice Thickness (feet)	Water Depth (feet)	Temp. (°C)	pH	Cond. umhos/cm at 25°C	Diss. Oxygen mg/l
Lake Claire								
1	7	Apr.12	3.7	0.6	0	7.8	2458	1.2
1	9	"	3.1	0.9	0	7.7	3600+	0
1	11	"	3.5	0.5	0	7.3	1967	0
2	7	"	4.0	0.1	0	7.2	3600+	0
2	11	"	3.8	0.2	0	7.6	3600+	0
2	13	"	4.4	0.2	0	7.5	3096	0
3	-	"	3.5	0.0	-	-	-	-
4	-	"	4.0	0.0	-	-	-	-
5	-	"	2.0	0.0	-	-	-	-
6	-	"	2.5	0.0	-	-	-	-
7	-	"	2.0	0.0	-	-	-	-
8	3	"	3.8	0.2	0	7.6	3600+	0
8	5	"	3.8	0.2	0	7.4	3600+	0
8	15	"	3.6	0.4	0	8.1	3600+	0
9	-	"	3.0	0.0	-	-	-	-
10	5	"	3.1	0.5	0	7.6	1967	0
10	6	"	3.5	0.2	0	7.3	1657	0
11	-	"	-	0.0	-	-	-	-
12	-	"	-	0.0	-	-	-	-
Mamawi Lake								
13	-	Mar. 31	0.3	0.0	-	-	-	-
14	-	"	0.3	0.0	-	-	-	-
15	-	"	0.3	0.0	-	-	-	-
16	-	"	0.3	0.0	-	-	-	-
Baril Lake								
17	-	"	0.3	0.0	-	-	-	-
18	-	"	0.3	0.0	-	-	-	-
Richardson Lake								
19	-	"	1.5	0.0	-	-	-	-
20	-	"	1.5	0.0	-	-	-	-

Traverse Line No.	Stn. No.	Date 1971	Ice Thickness (feet)	Water Depth (feet)	Temp. (°C)	pH	Cond. µmhos/cm at 25°C	Diss. Oxygen mg/1
Lake Athabasca								
21	1	Mar. 31	2.5	1.0	0	7.4	419	3.9
21	2	"	3.9	1.0	0	7.4	419	6.0
21	3	"	3.1	2.0	0	7.3	419	5.4
21	4	"	2.9	2.0	0	7.3	319	7.1
21	5	"	2.3	2.5	0	7.5	109	8.2
21	6	"	2.8	1.6	0	7.4	109	9.3
21	7	"	2.7	1.0	0	7.4	182	8.2
21	8	"	3.0	0.8	0	7.4	182	8.3
22	1	"	3.4	0.3	0	7.6	100	6.8
22	2	"	3.4	0.3	0	7.6	146	5.9
22	3	"	3.7	0.9	0	7.4	137	6.1
22	4	"	4.0	1.6	0	7.2	91	6.5
22	6	"	2.9	2.9	0	7.6	382	7.3
22	7	"	3.5	1.9	0	7.7	382	8.1
22	8	"	3.6	0.5	0	7.7	209	7.6
22	9	"	3.6	0.5	0	7.8	219	7.5
23	1	Apr. 5	2.9	3.6	0	8.5	137	7.9
23	2	"	2.6	3.7	0	8.2	137	8.6
23	3	"	2.6	3.9	0	7.8	127	7.2
23	4	"	3.2	4.1	0	7.8	155	8.0
23	5	"	2.8	4.6	0	7.5	410	7.7
23	6	"	3.3	4.0	0	7.6	410	7.9
23	7	"	3.4	3.1	0	7.5	410	6.0
23	8	"	3.1	1.7	0	7.5	410	9.7
23	9	"	3.0	4.2	0	7.4	410	5.2
24	1	Apr. 4	3.0	2.6	0	7.8	127	8.7
24	2	"	2.5	8.4	0	7.9	109	8.6
24	3	"	2.6	8.5	0	7.8	118	5.0
24	4	Apr. 5	2.8	7.6	0	7.8	127	-
24	5	"	3.3	5.3	0	7.9	137	6.4
24	6	"	3.6	4.4	0	7.4	228	6.6
24	7	"	3.4	3.9	0	7.4	255	5.3
24	8	"	4.0	2.3	0	7.7	237	5.9
24	9	"	3.9	1.7	0	7.4	255	6.6
24	10	"	3.1	2.1	0	7.7	237	6.2
24	11	"	3.0	1.6	0	8.0	246	5.3
25	1	Mar. 31	2.6	5.1	0	7.9	127	6.1
25	2	"	3.5	5.0	0	7.7	109	6.8
25	3	"	2.9	6.4	0	7.8	91	8.0
25	4	"	2.9	7.4	0	7.9	109	6.0
25	5	"	3.1	7.8	0	8.1	109	-
25	6	"	3.2	8.4	0	7.4	109	7.4
25	7	"	3.1	0.6	0	7.7	137	7.0

Traverse Line No.	Stn. No.	Date 1971	Ice Thickness (feet)	Water Depth (feet)	Temp. (°C)	pH	Cond. µmhos/cm at 25°C	Diss. Oxygen mg/1
Birch River								
41	2	Apr. 8	2.1	5.0	0	7.7	2049	0.6
41	3	"	2.0	5.8	0	8.1	1912	1.3
41	5	"	1.7	2.0	0	7.9	1275	3.2
McIvor River								
42	5	Apr. 8	1.6	0.2	0	7.7	3600+	4.6
42	6	"	2.7	3.8	0	7.9	3600+	4.7
42	7	"	2.6	2.4	0	8.4	3600+	5.0
Athabasca River								
Below Fort McMurray		Apr. 6	-	-	0	7.9	427	-
48	5	Apr. 4	2.3	2.7	0	7.8	437	6.2
48	7	"	2.2	7.8	0	7.8	446	10.5
48	9	"	2.4	24.6	0	7.8	455	-
Athabasca River - Fletcher Channel								
49	9	Apr. 7	2.6	1.3	0	7.7	419	5.7
49	11	"	2.8	4.6	0	7.5	483	5.0
49	12	"	3.2	7.2	0	7.5	473	6.1
Athabasca River - Goose Island Channel								
50	4	Apr. 7	2.2	4.2	0	7.6	401	6.6
50	8	"	2.7	7.5	0	8.0	401	5.8
50	11	"	3.2	7.8	0	8.5	410	6.6
Athabasca River - Big Point Channel								
51	3	Apr. 7	2.0	5.1	0	8.0	392	5.7
51	5	"	2.4	8.2	0	8.2	410	5.1
51	7	"	2.5	8.5	0	8.4	437	5.4
Embarras River								
47	5	Apr. 4	2.0	1.0	0.5	7.0	910	0
47	6	"	2.1	2.0	0.5	7.3	983	0
47	8	"	1.9	0.5	0.5	7.9	947	0

Traverse Line No.	Stn. No.	Date 1971	Ice Thickness (feet)	Water Depth (feet)	Temp. (^oC)	pH	Cond. µmhos/cm at 25^oC	Diss. Oxygen mg/1
Prairie River								
54	4	Apr. 3	3.8	4.7	0	7.1	1366	1.0
54	5	"	4.3	3.0	0	-	1311	1.2
54	6	"	4.3	0.7	0	-	1366	1.7
Claire River								
52	2	Apr. 3	2.0	0.5	0.5	7.0	501	1.0
52	4	"	3.0	5.0	0.5	7.2	546	0
Chanel des Quatre Fourches								
43	2	Apr. 3	2.3	0.6	0	7.8	337	5.1
43	4	"	2.4	2.7	0	7.4	328	6.0
43	6	"	2.1	3.0	0	7.5	310	5.0
44	4	Apr. 3	2.0	5.3	0	7.7	382	5.5
44	5	"	2.1	7.2	0	7.7	346	6.3
44	6	"	2.0	9.1	0	7.7	328	-
45	-	Apr. 3	2.1	0	-	-	-	-
46	4	Apr. 3	2.8	2.5	0	7.6	346	6.3
46	7	"	2.5	3.1	0	7.7	346	5.5
46	9	"	3.0	1.7	0	7.5	410	5.3
Rivere des Rochers								
53	6	Apr. 11	3.7	24.4	0	-	346	8.9
53	8	"	3.4	27.9	0	-	228	7.7

TABLE II

WATER QUALITY ANALYSIS

CALGARY LABORATORIES

(mg/1)

	Lake Claire				Lake Athabasca				
Station No.	1-9	2-11	8-15	10-6	21-6	23-4	24-5	24-9	25-3
Date	Apr. 12	Apr. 12	Apr. 12	Apr. 12	Mar. 31	Apr. 5	Apr. 5	Apr. 5	Apr. 5
Temperature (^{o}C)	23.8	24.5	23.2	22.0	25.2	24.4	24.4	23.4	24.6
Turbidity (TTU)	88	125	37	62	12	17	2.9	10	2.8
Color (Pt-Co Units)	180	200	140	95	10	7	5	20	5
pH	7.9	7.9	8.0	7.6	7.9	7.7	7.7	7.3	7.7
Alkalinity (total)	903	834	1322	315	37.2	42.5	45.2	58.6	35.9
Suspended Matter (total)	-	-	-	-	2.4	2.8	-	-	-
Conductance (umhos/cm @ 25°C)	4980	4710	6940	2080	102	115	121	257	102
Hardness as $CaCO_3$ (total)	1823	1776	2819	482	41.8	48.0	50.6	106.0	41.5
Aluminum	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium	0.50	0.61	0.66	0.25	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	1.05	0.95	1.15	0.48	0.03	0.04	0.03	0.04	0.03
Cadmium	<0.0005	0.0015	0.0010	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Calcium	514	488	778	128	11.1	13.5	14.3	26.0	11.6
Carbon - total inorganic	175	150	215	65	8	10	12	14	10
- total organic	195	195	190	70	5	6	6	5	6
Chromium	<0.02	< 0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cobalt	<0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	0.019	0.019	0.019	0.008	0.001	0.001	0.001	0.001	0.001
Iron	0.17	0.17	0.11	0.21	0.02	0.02	0.02	0.15	0.02
Lead	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Lithium	0.25	0.22	0.32	0.12	<0.004	<0.004	<0.004	<0.004	<0.004
Magnesium	131	135	213	39	3.4	3.5	3.6	10.0	3.1
Manganese	0.9	5.2	7.5	4.8	<0.01	<0.01	0.01	<0.01	0.02
Mercury - soluble	<0.00005	-	0.00007	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
- total	<0.00005	0.00013	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Nickel	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Potassium	12.5	10.0	22.5	5.0	0.9	1.0	1.1	1.2	1.0
Sodium	516	469	742	250	3.4	3.5	3.9	5.8	3.5

TABLE II (cont'd)

	Lake Claire				Lake Athabasca				
Strontium	3.0	2.9	3.3	1.2	0.05	0.10	0.10	0.30	0.05
Thallium	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Zinc	0.009	0.001	0.010	0.004	0.003	0.003	0.005	0.003	0.004
Chloride	1070	940	1490	361	4.0	4.3	4.6	4.3	4.3
Fluoride	-	-	-	-	0.06	0.06	0.06	< 0.05	0.06
Nitrogen - Nitrate (N)	0.03	< 0.01	2.8	0.01	0.17	3.8	0.08	0.18	0.05
- Kjeldahl (N)	-	-	-	15.2	< 0.01	0.11	0.21	0.16	0.15
- Total (N)	-	-	-	15.2	0.17	3.91	0.29	0.34	0.20
Phosphate - Ortho (PO_4)	0.06	0.03	0.02	0.02	0.01	0.02	0.01	0.02	0.01
- Inorganic (PO_4)	0.15	0.13	0.10	0.05	0.02	0.02	0.02	0.02	0.01
- Total (PO_4)	1.3	1.0	0.58	1.4	0.06	0.09	0.03	0.05	0.02
Silica	-	-	-	-	3.6	3.7	4.0	11.3	3.5

NOTE: All results are for soluble constituents unless otherwise stated.

TABLE

BIRCH RIVER ICE COVER SURVEY

MARCH 15-16, 1972

Source	Latitude	Longtitude	Date of Sampling	Time	Ice Depth In Approx.	pH	D.O. mg/1	Temp. (^{o}C)
Birch River at Modere Creek #1	58^{o}26'18"	112^{o}23'42"	March 15/72	15:05	30	6.7	1.33	0.25^{o}C
Birch River #2	58^{o}26'48"	112^{o}22'42"	March 15/72	15:35	36	6.5	.12	0.25^{o}C
Birch River #3	58^{o}26'42"	112^{o}21'00"	March 15/72	15:45	34	-	.65	0.25^{o}C
Birch River #4	58^{o}26'24"	112^{o}18'48"	March 15/72	15:50	35	-	.76	0.25^{o}C
Birch River #5	58^{o}27'42"	112^{o}18'24"	March 15/72	16:00	38	-	.17	0.25^{o}C
Birch River #6	58^{o}28'30"	112^{o}17'24"	March 15/72	16:07	36	-	1.85	0.25^{o}C
Birch River #7	58^{o}29'30"	112^{o}16'30"	March 15/72	16:15	36	-	1.09	0.25^{o}C
Birch River #8	58^{o}30'00"	112^{o}13'48"	March 15/72	16:21	32	-	.84	0.25^{o}C
Birch River #9	58^{o}31'12"	112^{o}14'30"	March 15/72	16:27	36	-	1.33	0.25^{o}C
Birch River #10	58^{o}31'51"	112^{o}14'36"	March 15/72	16:35	36	-	1.29	0.25^{o}C
Birch River #11	58^{o}32'42"	112^{o}15'18"	March 15/72	16:43	30	-	.88	0.25^{o}C
Mouth Birch R. #12	58^{o}34'00"	112^{o}16'36"	March 15/72	17:12	34	-	1.01	0.25^{o}C
Lake Claire near mouth of Prairie River	58^{o}35'30"	112^{o}17'30"	March 15/72	17:35	44	-	1.10	0.25^{o}C
Lake Athabasca at Ft. Chipewyan	58^{o}42'00"	111^{o}09'00"	March 16/72	09:35	40	7.1	11.51	0.25^{o}C

APPENDIX C

TABLE I

Exchangeable and Acid Soluble Analysis of Sediments

Peace-Athabasca Delta Lakes
(mg/100 gms over-dry weight unless otherwise Stated)

Parameters	Lake Baril	Lake Athabasca			Lake Claire			Lake Mamawi	
	Center	West	Center	East	West	East	South	West	East
Sample Texture	Clay	Clay	Clay	Clay	Clay	Clay	Fine Clay	Clay	Clay
Mixture %	1.6	0.90	1.6	2.1	2.3	0.9	0.3	1.3	1.6
Volatile %	7.1	5.00	6.8	6.9	7.4	4.7	0.8	5.9	5.5
Al - Exch.	0.74	0.30	-	-	0.75	<0.10	0.15	<0.10	<0.10
- Sol.	780	550	775	755	635	580	175	480	505
Ba - Exch.	8.9	5.0	-	-	4.1	4.3	0.92	4.3	4.3
- Sol.	15.9	10.1	14.5	13.1	9.4	8.1	2.8	9.1	8.3
B - Exch.	0.22	0.09	-	-	0.17	0.15	0.03	0.17	0.09
- Sol.	-	-	-	-	-	-	-	-	-
Ca - Exch.	735	1000	-	-	350	755	65	385	385
- Sol.	1110	2065	970	690	505	1510	300	885	935
Cu - Exch.	0.05	0.04	-	-	0.05	0.04	<0.01	0.03	0.03
- Sol.	3.3	2.3	2.8	2.6	2.3	2.4	0.3	1.8	1.6
Fe - Exch.	0.35	0.37	-	-	0.50	1.2	0.20	0.15	0.13
- Sol.	3030	1910	2750	2630	2550	1640	530	1890	1670
Pb - Exch.	<0.10	<0.10	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
- Sol.	1.9	1.5	1.8	1.8	1.5	1.4	0.35	1.2	1.2
Li - Exch.	0.03	0.02	-	-	0.04	0.02	<0.003	0.02	0.02
- Sol.	1.7	1.3	1.7	1.8	1.7	1.2	0.32	1.1	1.0
Mg - Exch.	63.1	42.5	-	-	74.3	35.2	13.2	47.5	43.1
- Sol.	665	765	590	600	450	675	410	540	565
Mn - Exch.	19.9	11.7	-	-	13.1	9.8	2.3	10.9	11.7
- Sol.	59.2	46.6	97.5	60.6	37.0	40.3	10.0	35.4	34.1
Hg - Exch.	0.0008	0.0003	-	-	0.0001	0.0003	<0.00005	<0.00005	<0.00005
- Sol.	0.017	0.015	0.017	0.016	0.015	0.016	0.003	0.013	0.010
K - Exch.	22.8	11.8	-	-	22.6	13.6	3.3	13.9	13.2
- Sol.	96.8	69.0	90.8	115	97.1	64.3	20.0	62.4	124
Na - Exch.	6.0	4.0	-	-	18.0	7.8	4.3	9.3	6.8
- Sol.	10.8	12.1	11.8	11.6	22.7	16.1	6.3	15.9	11.9
Sr - Exch.	2.2	2.8	-	-	2.8	2.4	0.35	1.8	1.6
- Sol.	4.3	6.3	5.8	4.8	5.1	5.3	1.0	4.0	3.3
Zn - Exch.	0.21	0.30	-	-	0.31	0.35	0.09	0.16	0.16
- Sol.	12.4	8.8	10.3	10.6	9.4	8.3	2.0	7.3	6.8

APPENDIX D

TABLE I

CHEMICAL LOADINGS TO LAKE CLAIRE BY PARAMETERS - 1971

BIRCH RIVER BASIN

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
Jan/71	1.5	0.61	143.04	0.02	7.96	0.03	1.44	5.92	42.56	323.82	18.13	0.01	481.10	0.00	0.17	0.37	222.05	550.38	1518.35
Feb/71	1.1	0.45	104.89	0.01	5.16	0.00	0.71	4.34	31.21	237.47	13.30	0.00	352.81	0.00	0.12	0.27	162.84	403.61	1112.40
March/71	0.6	0.24	57.21	0.01	3.18	0.01	0.58	2.37	17.02	129.53	7.25	0.00	192.44	0.00	0.07	0.15	88.82	220.15	607.33
Apr/71	87	13.95	2146.46	0.43	57.95	0.00	5.90	236.11	654.67	2307.45	375.63	0.00	2833.33	113.76	2.15	33.27	4164.14	5206.91	15510.18
May/71	95	16.41	3714.99	0.23	67.97	0.00	0.00	257.82	914.10	4277.51	398.45	0.00	5801.00	141.80	0.00	14.06	7136.99	8742.85	27048.15
June/71*	94	14.63	4865.69	0.30	9.25	0.00	0.00	126.44	1243.72	5953.60	261.15	0.07	7351.64	141.11	104.61	27.65	7162.03	11644.50	32998.09
July/71*	126	19.52	3974.66	0.67	33.46	0.01	0.00	208.97	687.12	1870.63	606.44	0.16	1418.39	290.61	23.69	152.13	6359.70	9264.96	20210.18
Aug/71	23	5.96	890.91	0.11	7.09	0.00	0.00	39.72	56.75	896.58	161.73	0.00	907.93	21.00	1.42	4.54	1588.88	1943.76	5540.14
Sept/71	139	36.01	7733.32	0.00	92.59	0.00	0.00	377.23	2023.35	15775.28	685.88	-	24005.86	149.18	1.71	29.15	12071.52	19543.60	72608.47
Oct/71	89	4.39	2195.81	0.11	72.46	0.00	2.53	120.77	428.18	4720.99	647.76	0.00	6312.95	68.07	3.29	26.35	3941.48	3921.35	20476.84
Nov/71	32	1.58	789.50	0.04	26.05	0.00	0.91	43.42	153.95	1697.43	232.90	0.00	2269.82	24.47	1.18	9.47	1417.16	1409.92	7362.42
Dec/71	13	0.64	320.74	0.02	10.58	0.00	0.37	17.64	62.54	689.58	94.62	0.00	922.12	9.94	0.48	3.85	575.72	572.78	2991.00
Total for Year	701.2	114.39	26937.22	1.95	393.70	0.05	12.44	1440.75	6315.17	38879.87	3503.24	0.24	52849.39	959.94	138.89	301.26	44891.33	63424.77	207974.55

*Includes Prairie River inflow during this month.

TABLE I (cont'd)

CHEMICAL LOADINGS TO LAKE CLAIRE BY PARAMETERS - 1971

MCIVOR RIVER BASIN

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
Jan/71	0.4	0.02	20.72	0.00	0.19	0.00	0.00	0.64	3.16	12.83	3.36	0.00	12.34	0.44	0.04	0.29	51.81	26.23	118.76
Feb/71	0.3	0.02	15.54	0.00	0.14	0.00	0.00	0.48	2.37	9.62	2.52	0.00	9.25	0.33	0.03	0.22	38.86	19.67	89.07
Mar/71	0.2	0.01	10.36	0.00	0.09	0.00	0.00	0.32	1.58	6.41	1.68	0.00	6.17	0.22	0.02	0.15	25.91	13.11	59.38
Apr/71	21	2.85	984.41	0.13	10.62	0.00	0.65	53.11	222.79	777.17	147.66	0.13	826.39	36.79	1.04	3.11	2979.14	1225.26	6649.57
May/71	23	3.69	1923.68	0.00	2.27	0.00	1.05	70.93	417.08	2156.33	215.63	0.00	2468.43	20.43	1.42	10.78	5447.58	2652.78	14046.09
June/71	10	1.48	524.28	0.04	2.59	0.00	0.12	24.67	104.86	494.67	81.42	0.10	619.27	19.37	2.71	1.48	1356.96	757.89	3607.36
Jul/71	19	4.69	719.56	0.14	20.86	0.21	0.70	77.35	140.63	494.55	135.94	0.09	339.86	65.39	3.98	3.75	2177.43	688.57	4524.33
Aug/71	5	1.05	463.83	0.02	0.37	0.04	0.00	13.57	94.37	425.59	55.51	0.01	473.70	4.63	0.12	2.59	1128.74	774.44	3045.64
Sept/71	33	7.33	2348.90	0.00	15.06	0.00	0.00	61.06	415.23	2116.86	268.68	0.12	2564.65	43.97	1.22	27.68	5088.60	3979.85	14919.88
Oct/71	21	1.30	1088.04	0.08	9.84	0.00	0.00	33.68	165.80	673.55	176.16	0.05	647.64	23.32	2.07	15.28	2720.09	1376.84	6235.15
Nov/71	7	0.43	362.68	0.03	3.28	0.00	0.00	11.23	55.27	224.52	58.72	0.02	215.88	7.77	0.69	5.09	906.70	458.95	2078.39
Dec/71	3	0.19	155.43	0.01	1.41	0.00	0.00	4.81	23.69	96.22	25.17	0.01	92.52	3.33	0.30	2.18	388.58	196.69	890.74
Total for Year	142.9	23.06	8617.43	0.45	66.72	0.25	2.52	351.85	1646.83	7488.32	1172.45	0.53	8276.10	225.99	13.64	72.60	22310.40	12170.28	56264.36

TABLE I (cont'd)

CHEMICAL LOADING TO PRAIRIE RIVER BY PARAMETERS - 1971

LAKE CLAIRE

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
Jan/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr/71	68	5.03	3187.62	0.34	4.19	0.00	0.00	247.46	847.24	2432.66	67.11	0.34	3632.21	98.98	1.68	50.33	5343.46	8057.74	19887.98
May/71	58	7.15	3040.82	0.14	1.43	0.00	0.00	157.41	851.43	4149.83	50.08	0.00	6081.65	114.48	0.00	36.49	5716.75	6898.94	23606.15
June/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug/71	40	3.45	1914.55	0.20	1.48	0.00	0.00	78.95	340.47	409.56	320.74	0.05	182.57	56.75	1.97	25.17	1036.22	6712.78	7678.92
Sept/71	172	16.97	9229.80	0.85	0.00	0.00	0.00	509.23	2355.19	6280.50	806.28	0.21	8062.81	182.47	0.00	82.75	11203.06	28709.76	52872.86
Oct/71	150	20.35	8974.44	0.37	14.80	0.00	0.00	629.14	2201.98	9529.56	758.66	0.19	12693.74	209.10	18.50	203.54	16968.17	20977.43	62556.25
Nov/71	39	3.37	1866.68	0.19	1.44	0.00	0.00	76.98	331.96	399.32	312.72	0.05	178.01	55.33	1.92	24.54	1010.32	6544.96	7486.95
Dec/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for Year	527	56.32	28213.91	2.09	23.34	0.00	0.00	1699.17	6928.27	23201.43	2315.59	0.84	30830.99	717.11	24.07	422.82	41277.98	77901.61	174089.11

TABLE I (cont'd)

CHEMICAL LOADINGS TO MAMAWI LAKE BY PARAMETERS - 1971

PRAIRIE RIVER AND CHENAL DES QUATRE FOURCHES

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
Jan/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr/71	68	5.03	3187.62	0.34	4.19	0.00	0.00	247.46	847.24	2432.66	67.11	0.34	3632.21	98.98	1.68	50.33	5343.46	8057.74	19887.98
May/71	58	7.15	3040.82	0.14	1.43	0.00	0.00	157.41	851.43	4149.83	50.08	0.00	6081.65	114.48	0.00	36.49	5716.75	6898.94	23606.15
June/71	78.6*	7.76	3975.40	0.19	1.94	0.00	0.00	203.62	989.00	3364.55	155.14	0.19	4673.52	88.23	66.90	29.09	5197.11	11819.54	24575.07
July/71	67.9*	2.51	3007.04	0.17	2.51	0.00	0.00	125.64	670.09	678.47	519.32	0.00	351.80	89.62	1.68	41.88	1482.58	11435.78	12606.70
Aug/71	40	3.45	1914.55	0.20	1.48	0.00	0.00	78.95	340.47	409.56	320.74	0.05	182.57	56.75	1.97	25.17	1036.22	6712.78	7678.92
Sept/71	172	16.97	9229.80	0.85	0.00	0.00	0.00	509.23	2355.19	6280.50	806.28	0.21	8062.81	182.47	0.00	82.75	11203.06	28709.76	52872.86
Oct/71	150	20.35	8974.44	0.37	14.80	0.00	0.00	629.14	2201.98	9529.56	758.66	0.19	12693.74	209.10	18.50	203.54	16968.17	20977.43	62556.25
Nov/71	39	3.37	1866.68	0.19	1.44	0.00	0.00	76.98	331.96	399.32	312.72	0.05	178.01	55.33	1.92	24.54	1010.32	6544.96	7486.95
Dec/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for Year	673.5	66.59	35196.35	2.45	27.79	0.00	0.00	2028.43	8587.36	27244.45	2990.05	1.03	35856.31	894.96	92.65	493.79	47957.67	101156.93	211270.88

*Flow exclusively from Chanel des Quatre Fourche to Mamawi.

TABLE I (cont'd)

CHEMICAL LOADINGS TO CHENAL DES QUATRE FOURCHES

MAMAWI LAKE

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
Jan/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr/71	68	4.19	3187.62	0.17	2.10	0.00	0.00	150.99	754.96	1761.58	335.54	0.08	2181.00	83.05	29.36	33.55	2994.69	10839.09	16858.33
May/71	63	3.89	2953.24	0.16	1.94	0.00	0.00	139.89	699.45	1632.05	310.87	0.08	2020.64	76.94	27.20	31.09	2774.49	10042.10	15618.78
June/71	53*	6.54	2837.53	0.20	0.65	0.00	0.00	215.76	712.65	3465.18	58.84	0.07	5328.54	80.42	104.61	21.58	5138.93	6662.85	21253.69
July/71	44*	4.34	1992.02	0.16	1.09	0.00	0.00	97.70	434.23	879.31	141.12	0.16	922.73	48.85	13.57	20.63	2181.99	6034.28	9710.45
Aug/71	74.5	4.60	3492.32	0.18	2.30	0.00	0.00	165.43	827.13	1929.97	367.61	0.09	2389.48	90.98	32.17	36.76	3280.94	11875.18	18469.80
Sept/71	182	11.23	8531.58	0.45	5.61	0.00	0.00	404.13	2020.64	4714.82	898.06	0.22	5837.40	222.27	78.58	89.81	8015.19	29010.51	45120.88
Oct/71	150	9.25	7031.52	0.37	4.63	0.00	0.00	333.07	1665.36	3885.84	740.16	0.19	4811.04	183.19	64.76	74.02	6605.93	23909.76	37187.54
Nov/71	39	2.41	1828.20	0.10	1.20	0.00	0.00	86.60	432.99	1010.32	192.44	0.05	1250.87	47.63	16.84	19.24	1717.54	6216.54	9668.76
Dec/71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals for Year	673.5	46.45	31854.03	1.79	19.52	0.00	0.00	1593.57	7547.41	19279.07	3044.64	0.94	24741.70	833.33	367.09	326.68	32709.70	104590.31	173888.24

*Flow was out of Mamawi Lake to Lake Claire via Prairie River

TABLE II

CHEMICAL LOADINGS TO LAKES CLAIRE † MAMAWI SYSTEMS BY PARAMETERS

5 YEAR HYPOTHETICAL SEQUENCE

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
1972	1203	207.76	64109.70	4.45	623.29	1.48	19.29	2968.04	12762.58	63367.69	8458.92	4.45	74052.64	1840.19	89.04	519.41	134155.48	103837.83	414336.05
1973	1203	207.76	64109.70	4.45	623.29	1.48	19.29	2968.04	12762.58	63367.69	8458.92	4.45	74052.64	1840.19	89.04	519.41	134155.48	103837.83	414336.05
1974	1203	207.76	64109.70	4.45	623.29	1.48	19.29	2968.04	12762.58	63367.69	8458.92	4.45	74052.64	1840.19	89.04	519.41	134155.48	103837.83	414336.05
1975	1203	207.76	64109.70	4.45	623.29	1.48	19.29	2968.04	12762.58	63367.69	8458.92	4.45	74052.64	1840.19	89.04	519.41	134155.48	103837.83	414336.05
1976	1203	207.76	64109.70	4.45	623.29	1.48	19.29	2968.04	12762.58	63367.69	8458.92	4.45	74052.64	1840.19	89.04	519.41	134155.48	103837.83	414336.05
Total	6015	1038.80	320548.50	22.25	3116.45	7.40	96.45	14840.20	63812.90	316838.45	42294.60	22.25	370263.20	9200.95	445.20	2597.05	670777.40	519189.15	2071680.25

TABLE II (cont'd)

CHEMICAL LOADINGS FROM LAKES CLAIRE † MAMAWI SYSTEMS BY PARAMETERS

5 YEAR HYPOTHETICAL SEQUENCE

(metric tons)

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
1972	527	32.51	24704.07	1.30	16.25	0.00	0.00	1170.19	5850.96	13652.25	2600.43	0.65	16902.79	643.61	227.54	260.04	23338.85	84002.95	130782.20
1973	1097	67.66	51423.85	2.71	33.83	0.00	0.00	2435.87	12179.33	28418.44	5413.04	1.35	35184.74	1339.73	473.64	541.30	48582.01	174860.04	272235.45
1974	1397	86.17	65486.89	3.45	43.08	0.00	0.00	3102.01	15510.05	36190.12	6893.36	1.72	44806.82	1706.11	603.17	689.34	61867.88	222679.55	346684.53
1975	1327	81.85	62205.51	3.27	40.92	0.00	0.00	2946.58	14732.89	34376.73	6547.95	1.64	42561.67	1620.62	572.95	654.79	58767.84	211521.67	329313.08
1976	1097	67.66	51423.85	2.71	33.83	0.00	0.00	2435.87	12179.33	28418.44	5413.04	1.35	35184.74	1339.73	473.64	541.30	48582.01	174860.04	272235.45
Totals	5445	335.85	255244.17	13.44	167.91	0.00	0.00	12090.52	60452.56	141055.98	26867.82	6.71	174640.76	6649.80	2350.94	2686.77	241138.59	867924.25	1351250.71

TABLE III

CHEMICAL BALANCE - 1971

(metric tons)

LAKE CLAIRE SYSTEM

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
	INPUT																		
1971	844	137.45	35554.65	2.40	460.42	0.30	14.96	1792.60	7962.00	46368.19	4675.69	0.77	61125.49	1185.93	152.53	373.86	67201.73	75595.05	264247.91
	OUTPUT																		
1971	527	56.32	28213.91	2.09	23.34	0.00	0.00	1699.17	6928.27	23201.43	2315.59	0.84	30830.99	717.11	24.07	422.82	41277.98	77901.61	174089.11
	ACCUMULATION																		
1971	317	81.13	7340.74	0.31	437.08	0.30	14.96	93.43	1033.73	23166.76	2360.10	-0.07	30294.50	468.82	128.46	-48.96	25923.75	-2306.56	90158.80

MAMAWI LAKE SYSTEM

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
	INPUT																		
1971	673.5	66.59	35196.35	2.45	27.79	0.00	0.00	2028.43	8587.36	27244.45	2990.05	1.03	35856.31	894.96	92.65	493.79	47957.67	101156.93	211270.88
	OUTPUT																		
1971	673.5	46.45	31854.03	1.79	19.52	0.00	0.00	1593.57	7547.41	19279.07	3044.64	0.94	24741.70	833.33	367.09	326.68	32709.07	104590.31	173888.24
	ACCUMULATION																		
1971	0	20.14	3342.32	0.66	8.27	0.00	0.00	434.86	1039.95	7965.38	-54.59	0.09	11114.61	61.63	-274.44	167.11	15247.97	-3433.38	37382.64

TABLE III (cont'd)

CHEMICAL BALANCE

5 YEAR HYPOTHETICAL SYSTEM

LAKE CLAIRE - MAMAWI SYSTEM

Date	Discharge 1000 ac.ft.	Boron	Calcium	Copper	Iron	Lead	Manganese	Potassium	Magnesium	Sodium	Silica	Zinc	Chloride	Total Nitrogen	Nitrates	Total Phosphates	Sulfates	Bicarbonates	Total Dissolved Solids
	INPUT																		
1972-77	6015	1038.80	320548.50	22.25	3116.45	7.40	96.45	14840.20	63812.90	316838.45	42294.60	22.25	370263.20	9200.95	445.20	2597.05	670777.40	519189.15	2071680.25
	OUTPUT																		
1972-77	5445	335.85	255244.17	13.44	167.91	0.00	0.00	12090.52	60452.56	141055.98	26867.82	6.71	174640.76	6649.80	2350.94	2686.77	241138.59	867924.25	1351250.71
	ACCUMLATION																		
1972-77	570	702.95	65304.33	8.81	2948.54	7.40	96.45	2749.68	3360.34	175782.47	15426.78	15.54	195622.44	2551.15	-1905.74	-89.72	429638.81	-348735.10	720429.54

SECTION P

SECTION P

AN EMPIRICAL RECONSTRUCTION OF WATER LEVELS FOR LAKE ATHABASCA (1810-1967) BY ANALYSIS OF TREE RINGS

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INTRODUCTION

The recent construction of the W. A. C. Bennett Dam in the headwaters of the Peace River has aroused concern regarding the effects of regulated streamflow on the ecology of the Peace-Athabasca delta area. An interdisciplinary study was launched to determine recent runoff and lake-level patterns and their effect on animal and plant life in the delta. However, the water level and runoff records are relatively short. Water levels of Lake Athabasca have been recorded only since 1930, and records are incomplete. Measurements of runoff for the two major river systems are also limited. The longest and most consistent record for the Peace River is from the town of Peace River, about 350 miles (560 km) upstream from the delta. It begins in 1916, but information from 1932 to 1958 is missing. The record for the Athabasca River is obtained at the town of Athabasca, about 300 miles (480 km) upstream from the delta. It begins in 1913 but is fragmentary for the period 1932-1958. Some evidence indicates that these existing records are not representative of runoff and water levels over a comparatively long period of time. This study is an attempt to reconstruct the levels in Lake Athabasca by study of tree-ring series and to estimate any long-term trends that may not be present in the historical measurements.

Techniques for reconstructing hydrologic records from tree-ring data have recently been developed at the Laboratory of Tree-Ring Research. These techniques utilize multivariate analysis to calibrate tree-ring widths with runoff for periods covered by existing historical records, and these relationships are then applied to estimate runoff from tree-ring data for years for which no direct measurements of runoff are available. The lengthened record permits improved estimates of the long-term mean, variance, and first-order serial correlation--three useful statistics in hydrology. The nonrandom, long-term or low-frequency changes resulting from climatic variation recorded by the tree rings are transferred to the hydrologic estimates. Since the climate of Western Canada has varied markedly in recent years, the reconstruction of hydrologic records by using some substitute for climate, such as tree rings, is superior to synthesizing the longer hydrologic records by purely statistical means.

OBJECTIVES

In the past, the ecology of the delta has been sustained by frequent high-water stages that fill the lakes, depressions, and sloughs with water and inundate much of the rest of the area in June and July. The summer high level of Lake Athabasca starts receding by late August and September, and water levels in the smaller bodies, which receive outflow from the larger lake, follow in a similar recession curve at a reduced but continuous rate, until the minimum water levels are reached usually in March. The major factors controlling water levels within the delta region are the level of water in Lake Athabasca and the occurrence of high-water stages on the Peace and Athabasca Rivers.

Relatively old white spruce growing on the crests of natural levees along the major waterways in the area were found to have rings that varied in width from year to year. This variation was similar for all trees in a local stand, and it was inferred that some environmental factor common to the trees of the stand had become limiting to growth. The trees are 300 miles (480 km) south of the arctic tree line, so it is possible that soil moisture could have been limiting to processes that ultimately affect growth. Also, conditions of flooding might become so extreme as to affect aeration and limit processes affecting growth. If tree

growth becomes sufficiently limited by soil moisture conditions, then ring-width series from selected locations within the delta might serve as records of water levels. They might then be used to reconstruct the long-term changes in water levels of the Peace-Athabasca delta system.

The specific objective of this study is to calibrate ring widths of trees from stands at several delta locations with existing records of water levels from Lake Athabasca. If the variance explained in the calibration is sufficiently high, the ring widths can be used to estimate the water levels of Lake Athabasca that existed prior to the existent records. These extended records can be utilized to evaluate any bias the short historical records of lake levels might contain.

DENDROCHRONOLOGY

Tree Growth Model

Two climatic factors--precipitation and temperature--control the water balance in a tree. The water balance affects processes governing manufacture and consumption of food as well as processes of growth. In semiarid regions, seasonal variations in these two climatic factors are reflected in the ring-widths of conifers. By contrast, trees near the arctic tree line, that is, at elevations within 325 ft (100 m) of the upper climatic limit of the species, respond more to temperature before and during the growing season than to available moisture at the site. The best records of temperature seem to come from trees that grow in outliers north of the arctic tree line. However, the range of sites where low temperature alone is limiting to growth is restricted, and in certain areas high-altitude trees that grow near their temperature limits are also limited by fluctuations in soil moisture; i. e., <u>both</u> low moisture and low temperature are limiting at certain times of the year. Because the white spruce in the Peace-Athabasca delta region are not far enough north for their growth processes to be severely limited by low temperature, their rings do not readily reflect temperature variations.

It was at first surprising to find that the widths of

rings in the trees from the delta region vary from year to year as much as they do and that they cross-date so well from site to site. However, the climate of the Peace-Athabasca region is known to be dry as well as cool. (Mean annual precipitation at Fort Vermilion is only 14.31 in. (36.35 cm).) It is also noted that white spruce are most vigorous and oldest on well-drained sites at the tops of levees. Trees grow well as long as an active stream is nearby, but if a stream meander is cut off or migrates, there appears to be deterioration in growth in white spruce and species typical of wetter areas begin to invade the site. This implies that some factor related to the presence of the river--probably water stage--is affecting the growth of white spruce on the natural levees.

The growing season for white spruce was not actually observed but it probably begins in May or early June and ceases in August or September. Growth is dependent upon the maintenance of favorable water and food balances within the tree. Therefore, high growth may be dependent upon favorable balances for the entire photosynthetic period, which may begin in spring when needle temperatures remain above freezing (except for short periods at night) and end in autumn when night temperatures drop well below freezing. Growth may cease before the tree ceases to photosynthesize, so the

conditions of one season can influence the growth of the next season. In addition, excessive moisture (lack of soil oxygen) can limit root growth so that extensive flooding in one year can limit root growth and limit the ability of a tree to absorb water the following year. Flooding can also bring nutrients into the ecosystem which favor high growth in the following year. A thorough investigation of these possibilities would be worthy of further investigation, but such an investigation could not be accomplished in the time available for this study.

Therefore, an empirical model is assumed in which high or low water at different times in the year can affect the growth for that year and the growth for the following year. Individual sites may vary in their soil moisture and aeration characteristics, and the growth period may vary somewhat between sites. The model, therefore, must be flexible enough to allow for differences between sites, differences between immediate effects and lagging effects, differences in time of flooding, differences due to limiting effects of low moisture and of excessive moisture, and interactions where conditions may limit growth in one year but favor growth in the next.

Continuous records of lake levels are available for three periods within each year, so it is possible to assess

differences due to early or late occurrence of flood stages. By using canonical analysis as the appropriate statistical model, allowance is made for interactions in tree growth at each site and these are used to provide information on lake levels at three different times of the year.

Peace-Athabasca Delta Tree-Ring Samples

Six tree-ring sites were sampled within the delta region during May and early June, 1971. The locations of these sites (shown in Fig. 1) were largely determined by availability of old-aged trees, but where possible they were chosen so as to reflect differences in the water levels within the inlets and outlets of the delta hydrologic system. Specifically, the sampling scheme was designed to monitor the level of the Athabasca River (the Athabasca River site), the Peace River (the Peace River I site), and the main outflow channel of Lake Athabasca, Rivière des Rochers (Peace River II and Revillon Coupé sites). The other two sites, Claire River and Quatre Fourches, were sampled with the hope that they might show changes that occurred within the lake system. The Athabasca River and Claire River sites appeared to have relatively well-drained soils, and the Quatre Fourches and Revillon Coupé soils appeared to be poorly drained. (No sampling or detailed examination of soils was made.) The Peace River II

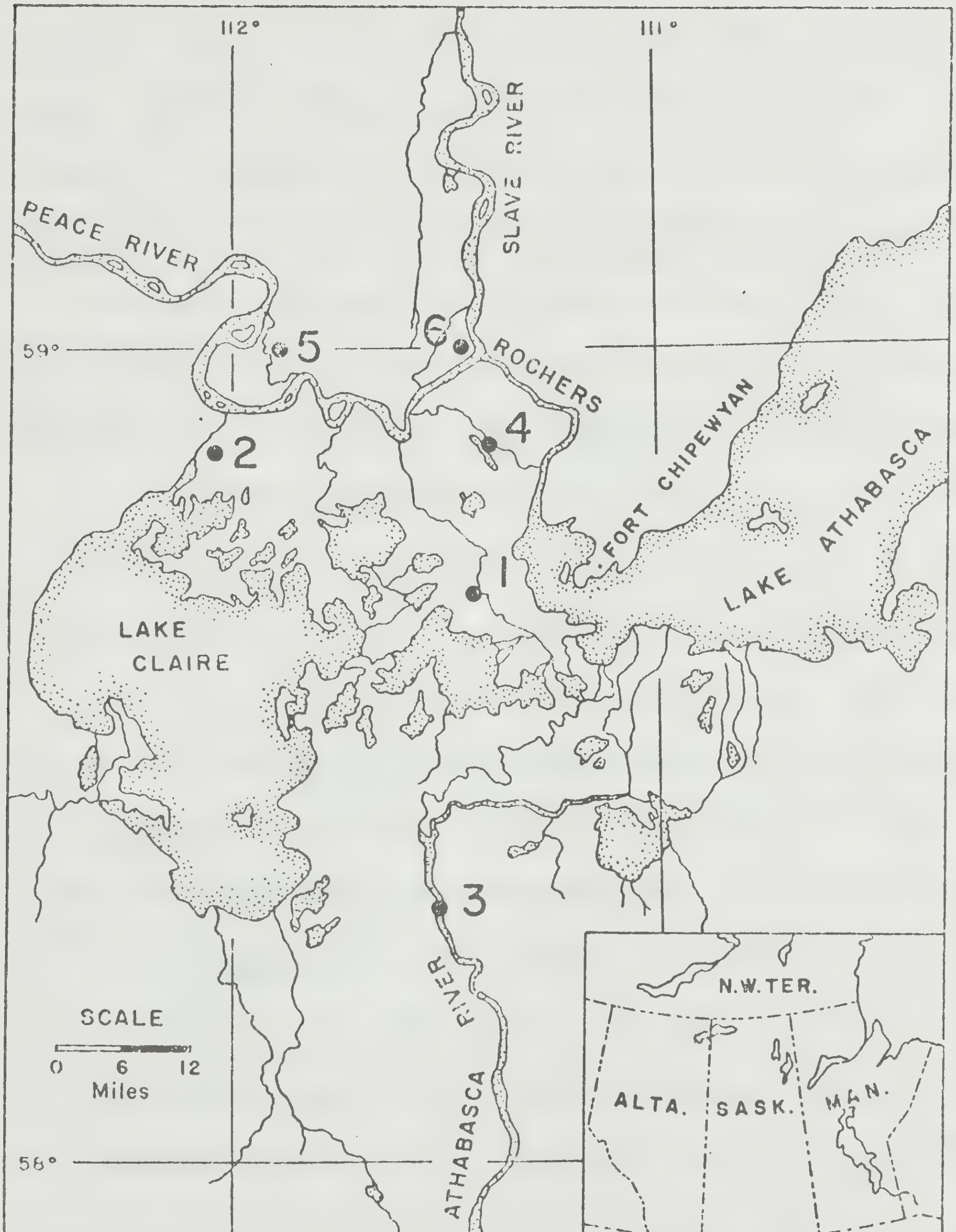

Figure 1. Locations of the 6 tree-ring sites.

1 Quatre Fourches
2 Claire River
3 Athabasca River
4 Revillon Coupe
5 Peace River I
6 Peace River II

site is located at the confluence of the Peace and the Rochers Rivers, and the Peace River I site is about 15 miles (24 km) upstream. Therefore, the differences in growth between these two sites should reflect high stages on the Rochers, the main outflow channel from Lake Athabasca.

Ten or more trees were sampled at each site, and two replications were obtained from each tree by extracting cores from opposite sides of the main stem. The cores were mounted and dated, and ring widths were measured to the nearest hundredth of a millimeter. Some samples were incomplete, so the minimum sample size was sometimes as low as eight trees per site, with two replications per tree.

Besides the trees sampled in 1971, additional tree-ring series were also available. One in particular is located near Patricia Lake in Banff National Park, which is near the headwaters of the Athabasca River. This chronology is included here to provide some visual comparison of moisture conditions in the headwater region of the Athabasca River. It is 800 miles (1300 km) southwest of the Lake Athabasca site.

The mean values (Appendix I) for each year in the seven chronologies are shown in Fig. 2. Table 1 includes the name, location, length of record, and several statistical measurements of the seven chronologies shown in Fig. 2.

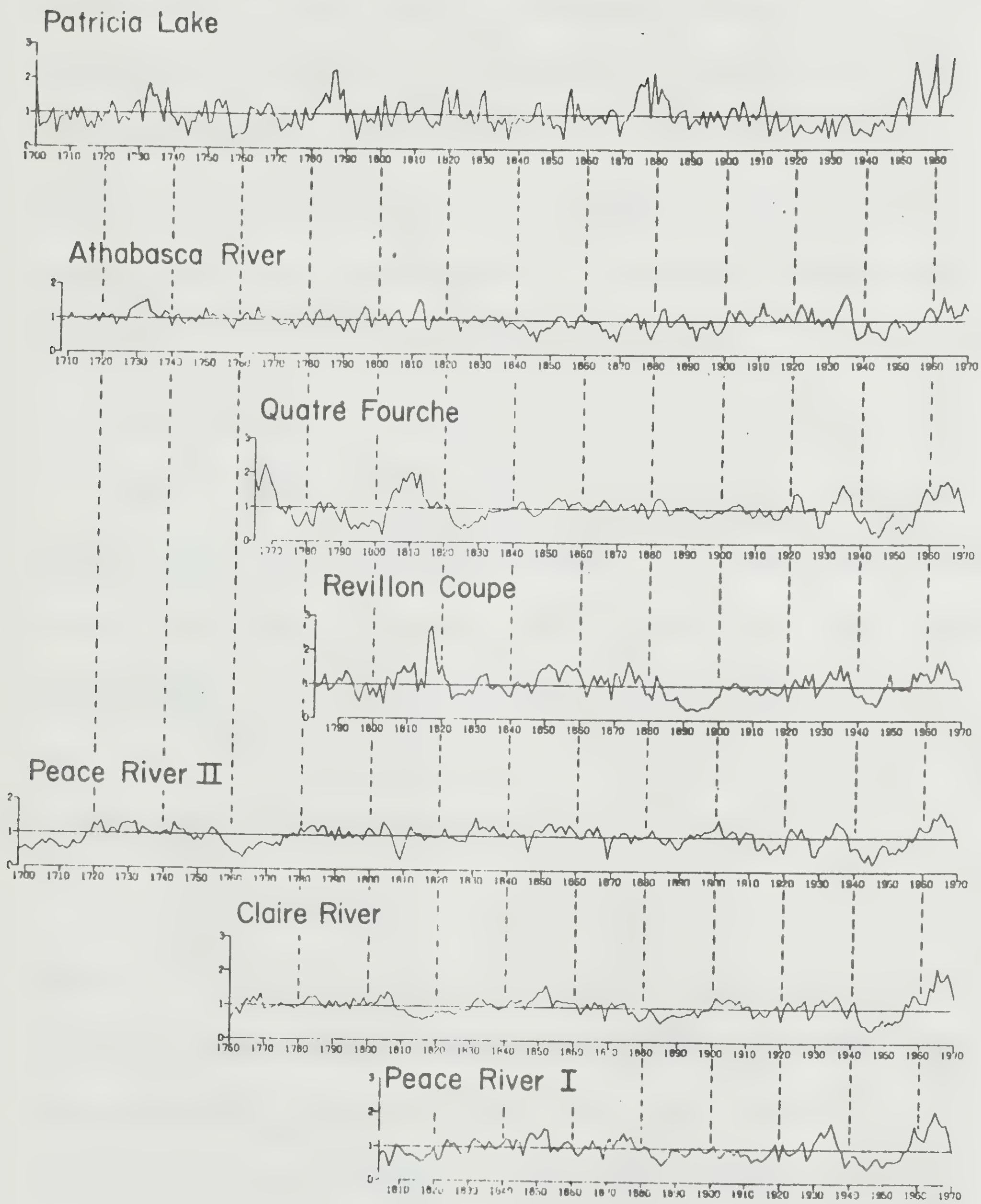

Figure 2. Plots of individual tree-ring series from the Peace-Athabasca Rivers Delta compared with a plot of a tree-ring series in the upper watershed of the Athabasca River (the Patricia Lake series).

Table 1. Data on location and statistics of chronologies shown in Figure 2.

Tree-Ring Series	Map Number	Location		Period of	Mean	Standard	First Order	Variance Components*		
		Latitude	Longitude	Record	Sensitivity	Deviation	Correlation	σ^2_Y	σ^2_{YT}	σ^2_{YTC}
Patricia Lake		52° 54'N	118° 06'W	1700-1965	0.35	0.44	0.48	57.23	21.78	20.99
Athabasca River	3	58° 22'N	111° 32'W	1708-1970	0.19	0.24	0.56	38.00	25.07	36.93
Quatre Fourches	1	58° 47'N	111° 27'W	1765-1970	0.21	0.38	0.33	54.48	14.08	31.44
Revillon Coupe´	4	58° 52'N	111° 18'W	1783-1970	0.22	0.38	0.66	44.50	30.00	25.50
Peace River II	6	58° 59'N	111° 26'W	1698-1970	0.17	0.27	0.75	53.34	9.64	27.02
Claire River	2	58° 53'N	111° 53'W	1760-1970	0.14	0.28	0.78	35.71	36.74	28.55
Peace River I	5	58° 58'N	111° 55'W	1604-1970	0.18	0.31	0.77	59.21	9.92	30.87

* Analysis of variance for years 1810 through 1970.

σ^2_Y is % variance in yearly indices common to all replications and all trees.

σ^2_{YT} is % variance attributed to differences among trees.

σ^2_{YTC} is % variance attributed to differences among replications.

In all series, the measured ring widths have been transformed to indices by fitting a straight line or modified exponential curve to the measured ring widths. Indices are formed by dividing the respective ring widths by the corresponding value of the growth function, and can be thought of as a percentage of the <u>expected</u> growth for the year. The transformation is necessary in order to convert the non-stationary ring-width series to one that is stationary (i.e., one that possesses a mean and variance that is not a function of time). This method, which is standard procedure at the Laboratory of Tree-Ring Research, is described in detail by Stokes and Smiley (1968). As a result of this transformation to indices, the mean of each series is equal to 1.00, whereas the variance is a function of the amount of ring-width variability in the site.

Visual inspection of the plots of the mean tree-ring series in Fig. 2 shows major growth anomalies in the past 30 to 40 years. The 13-year period 1955-1967 was a period of above-average growing conditions for trees on the delta sites. A similar trend evident in the Patricia Lake series in the headwaters of the Athabasca River seems to precede the high growth in the delta series by about 5 years. Prior to this period of high growth was about 18 years (1938-1955) of persistently low growth, which suggests that this 18-year

period was generally unfavorable to the trees, perhaps as a result of below-average soil moisture. All six delta series show a downward trend in growth from 1966 to 1970, including the Athabasca River site, which is obviously unaffected by the impoundment of water behind the W. A. C. Bennett Dam. This suggests that, irrespective of the dam closure, the growing conditions and, by inference, the moisture conditions of the Lake Athabasca delta region would have been reduced somewhat because of reduced precipitation. The 20-year period 1920-1940 was generally one of above-average growth for the delta trees, with 1935 being exceptionally high and 1927 being low growth years. The Patricia Lake chronology shows this same period as being generally below average for tree growth in the upper portions of the watershed. The period 1900-1920 was generally one of average tree growth, with the exception of the Athabasca River site, which is above average. The period 1880-1900 shows below-average growth in all except Peace River II and Athabasca River sites, but only in the Revillon Coupé chronology is this low growth comparable in degree to that in the period 1938-1955. This growth departure does not appear in the Patricia Lake chronology. It shows anomalously high growth for the period 1872-1882, but the high growth is not reflected in the growth at any of the six delta sites. In fact, the period 1878-1881 shows below-

average growth in most of the six delta chronologies. The period 1840-1859 was generally above average in growth for the delta area but mostly below average in the Patricia Lake and Athabasca River sites.

During the period 1820-1839, the first ten years was one of less than average tree-growth and the second ten years consisted of above-average growth. Ten years of below-average growth is most pronounced at the Quatre Fourches and Revillon Coupé chronologies, and only slightly apparent for the Peace River II and the Claire River sites and lacking in the chronologies from the Athabasca River site.

The 20-year period 1800-1819 shows rather diverse characteristics between the individual chronologies. The Quatre Fourches and Revillon Coupé chronologies show anomalously high growth while the Athabasca River, Peace River I, and Claire River sites show mostly below normal growth. The Peace River II and Patricia Lake sites show approximately average growth and are quite similar.

For years prior to 1800, the number of tree-ring samples available (see Appendix I) has diminished to the point that no comparison can be made among them. The sample size of most of the chronologies is limited prior to 1830, and in two chronologies the sample size is limited prior to 1860. Inferences concerning these earlier time periods would be

expected to have larger errors because of the reduction in the number of usable trees. In addition, the trees in these early time-periods were young and more likely to be influenced by local conditions about the tree than when they were older and assumed their present position as dominants in the stand.

A cross-correlation analysis was computed for 10-year overlapping 20-year subperiods between the individual chronologies illustrated in Fig. 2 (Table 2). This was done so that differences in chronologies could be spotted and potential inadequacies in the tree-ring record could be recognized. The correlations among chronologies are good and in many cases highly significant for even the early periods of record. Several chronologies from the Peace-Athabasca delta region show low or inverse correlation with the other chronologies in the early parts of the series. Good agreement among chronologies is apparent after 1850. The Patricia Lake chronology shows low correlation with the delta chronologies for 1910 to 1949 and inverse correlations for 1820 to 1859. This is perhaps not surprising because of the great distance between Patricia Lake and the delta sites (800 mi or 1300 km). Differences in the growth through time are likely to occur especially during periods when the climate of the Patricia Lake may be changing in opposite direction from the climate for the watershed as a whole. Also, there

TABLE 2. Correlation of 20-year sub-periods for each chronology with all other chronologies on Figure 2. In each case the name of the chronology which was correlated most highly (either positively or negatively) for that period is indicated.

PERIOD	PATRICIA LAKE	ATHABASCA RIVER	QUATRE FOURCHES	REVILLON COUPE	PEACE RIVER II	CLAIRE RIVER	PEACE RIVER I
1820-1839	Peace River I (r= -.56)	Revillon Coupe (r= .30)	Revillon Coupe (r= .59)	Quatre Fourches (r= .59)	Claire River (r= .70)	Peace River II (r= .70)	Patricia Lake (r= -.56)
1830-1849	Quatre Fourches (r= -.42)	Peace River II (r= .71)	Patricia Lake (r= -.42)	Claire River (r= .79)	Athabasca River (r= .71)	Revillon Coupe (r= .79)	Claire River (r= .77)
1840-1859	Peace River I (r= -.61)	Peace River II (r= .77)	Athabasca River (r= .76)	Peace River I (r= .77)	Revillon Coupe (r= .77)	Peace River I (r= .73)	Claire River (r= .73)
1850-1869	Quatre Fourches (r= .32)	Peace River II (r= .66)	Peace River I (r= .63)	Claire River (r= .85)	Revillon Coupe (r= .77)	Peace River I (r= .89)	Claire River (r= .89)
1860-1879	Peace River I (r= .58)	Revillon Coupe (r= .59)	Claire River (r= .70)	Peace River I (r= .83)	Claire River (r= .68)	Revillon Coupe (r= .76)	Revillon Coupe (r= .83)
1870-1889	Peace River II (r= .45)	Quatre Fourches (r= .67)	Athabasca River (r= .67)	Claire River (r= .81)	Revillon Coupe (r= .63)	Revillon Coupe (r= .81)	Claire River (r= .74)
1880-1899	Revillon Coupe (r= .52)	Revillon Coupe (r= .61)	Revillon Coupe (r= .74)	Quatre Fourches (r= .74)	Claire River (r= .62)	Peace River II (r= .62)	Claire River (r= .55)
1890-1909	Athabasca River (r= .54)	Revillon Coupe (r= .72)	Revillon Coupe (r= .66)	Athabasca River (r= .72)	Claire River (r= .48)	Revillon Coupe (r= .95)	Peace River II (r= .36)
1900-1919	Peace River II (r= .61)	Patricia Lake (r= .34)	Revillon Coupe (r= .78)	Quatre Fourches (r= .78)	Claire River (r= .79)	Peace River II (r=.79)	Claire River (r= .71)
1910-1929	Revillon Coupe (r= .22)	Quatre Fourches (r= .66)	Peace River II (r= .76)	Claire River (r= .85)	Claire River (r= .83)	Revillon Coupe (r= .85)	Claire River (r= .83)
1920-1939	Peace River I (r= .37)	Quatre Fourches (r= .74)	Peace River II (r= .87)	Claire River (r= .87)	Quatre Fourches (r= .87)	Revillon Coupe (r= .87)	Revillon Coupe (r= .80)
1930-1949	Athabasca River (r= .36)	Quatre Fourches (r= .85)	Peace River II (r= .96)	Quatre Fourches (r= .89)	Quatre Fourches (r= .96)	Quatre Fourches (r= .83)	Quatre Fourches (r= .88)
1940-1959	Revillon Coupe (r= .54)	Quatre Fourches (r= .85)	Peace River II (r= .92)	Peace River II (r= .66)	Quatre Fourches (r= .92)	Quatre Fourches (r= .85)	Quatre Fourches (r= .91)

may be different limiting factors (such as high temperature rather than low soil moisture) at Patricia Lake that could produce changes in growth not reflected in the Peace-Athabasca delta sites.

These data do show that the six delta sites are in good agreement at least back to 1850 and were not influenced by any sudden change in water course which would markedly alter the growth chronologies for an individual site. They also support the inference that growth conditions since 1930 have been different from conditions prior to 1930.

HYDROLOGY

A brief review of the hydrology is presented to aid interpretation of relationships among the six delta chronologies as well as their relationship to the water levels of Lake Athabasca.

Athabasca River

The Athabasca River begins in the Columbia icefields in the southern Canadian Rocky Mountains and flows some 800 miles (1320 km) northeast across the province of Alberta to Lake Athabasca. The total drainage area is approximately 60,000 square miles (155,000 km^2). From the 10% of the drainage area that is actually in the mountains originates about one-third of the flow, and thus the annual regime is typical of a stream that derives its flow from snowmelt runoff, that is, low winter and high spring and summer flows. The winter flows are low (averaging about 5,000 cfs) and relatively steady, whereas the spring and summer flows are generally higher--June and July are usually the high-flow months, with average discharge of 50,000 cfs--and much more variable as the river responds rapidly to snowmelt, rainfall, and melting of the ice fields in the mountains.

Peace River

The Peace River originates in the Ominesa and Rocky Mountains of Northeastern British Columbia and flows northeastward across the Great Plains toward Lake Athabasca. At its confluence with the major outlet channel of Lake Athabasca (the Rivière des Rochers) the Peace River changes name and becomes the Slave River. At this point, the Slave River turns north and ultimately flows into the Great Slave Lake. The drainage area of the Peace is approximately 113,000 square miles (300,000 km^2).

The Peace River, though not usually a contributor to Lake Athabasca, does flow into Lake Athabasca, principally via the Rochers and Quatre Fourches channels, under certain conditions of flood stage and lake levels. The conditions under which such reversal of flow direction occurs in the Rochers channel are detailed by Bennett (1970). The limited data available indicate that the average volume of water contributed by the Peace River to Lake Athabasca has been on the order of 1 million acre-feet per year, usually in June. However, perhaps more important than the total increment of water added is the fact that outflow from the lake is impeded during periods of high flow on the Peace River.

Annual Flow Regimes of the Peace and Athabasca Rivers

Kellerhols (1970) has compared the annual total monthly hydrographs for the Peace and Athabasca Rivers for two years, but a larger sample would have been desirable for an analysis of this type. Consequently, we analyzed the monthly runoff measurements from the two rivers for all years with complete available records by extracting the eigenvectors of the matrix of correlations for runoff among the 12 months in the water year. Eigenvectors describe orthogonal modes of behavior in the runoff regimes and are ordered from the highest to the lowest percentage of variance that they explain. Because of the symmetry of the correlation matrix, the signs in the eigenvector weights are arbitrary. That is, the particular mode of occurrence they describe in a sense can flip-flop, so the eigenvector weights may be plotted as they are or with the signs reversed. In some years the runoff departures from the mean appear like the plots in the figure. In other years, they appear like the plots with signs reversed.

Figures 3 and 4 show the first five eigenvectors of a total possible of 12 for the runoff of the Athabasca and Peace Rivers. Owing to incompleteness of records, the periods and sample sizes of the two analyses are not quite the same. Assuming the results are comparable, the following conclusions from the eigenvector analyses can be made.

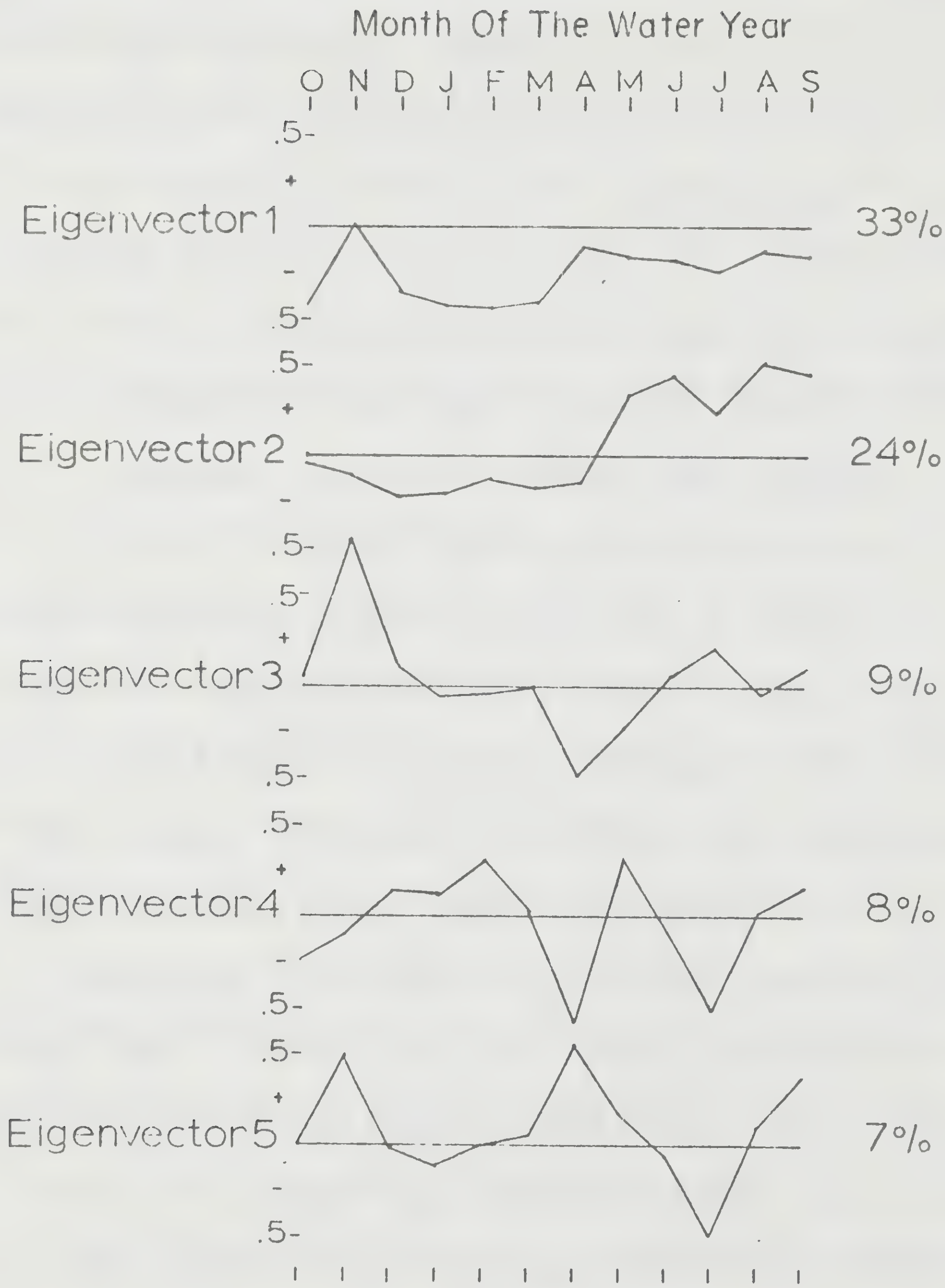

Figure 3. Eigenvectors of total monthly runoff for the Athabasca River at Athabasca and the percent variance in the original data they explain. The eigenvectors were extracted from the correlation matrix of monthly values for 31 years including 1915, 1916, 1917, 1918, 1920-30, 1952-67.

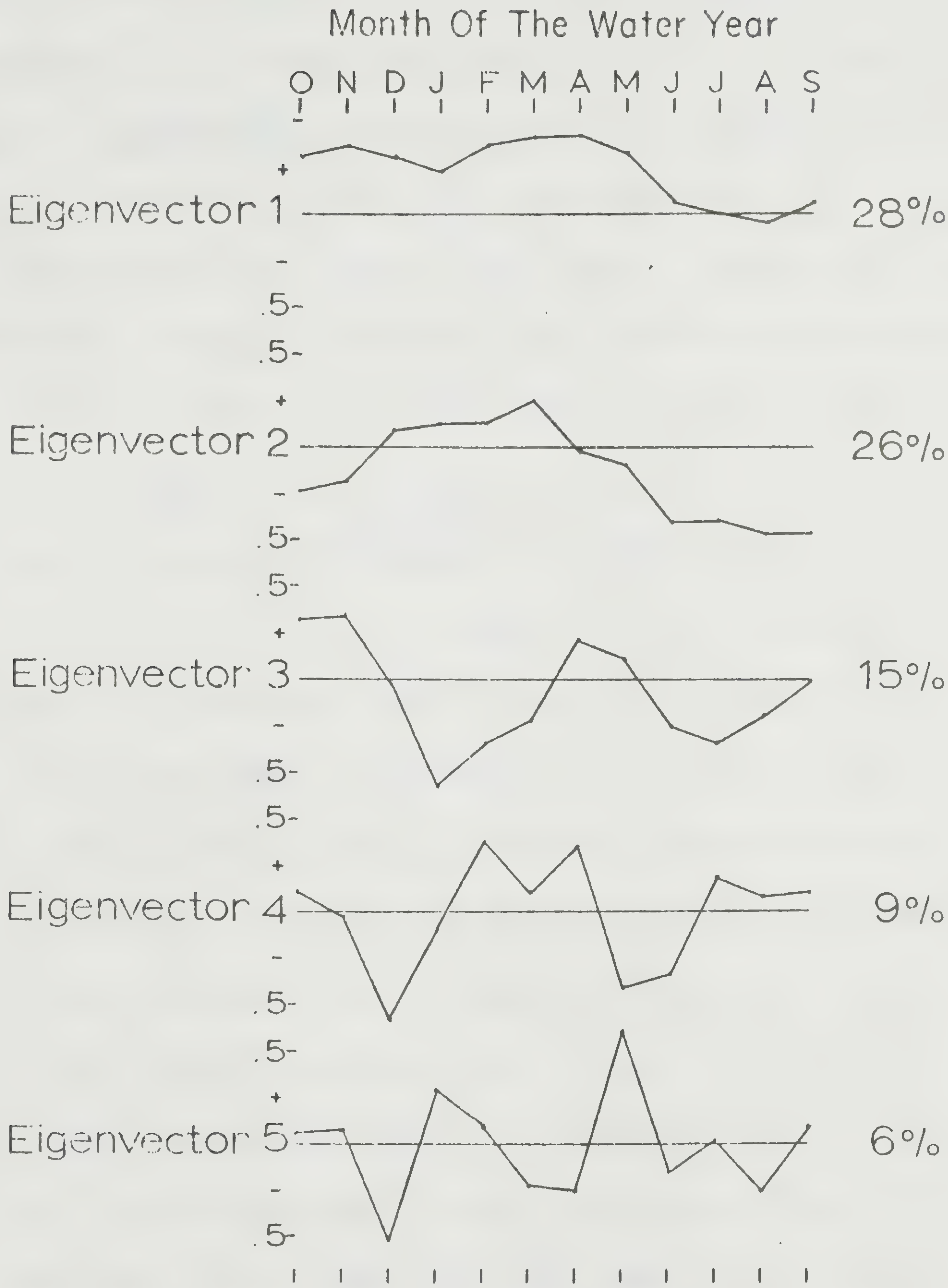

Figure 4. Eigenvectors of total monthly runoff for the Peace River at Peace River. The eigenvectors were extracted from the correlation matrix of monthly values for 25 years including 1916-1931, 1957-1967.

The first eigenvector accounts for more variance for the Athabasca River than for the Peace River, and in the former case the weights are all the same sign (except for November) and are not near zero. In both cases, the indication is that the high and low variations in runoff may be manifest throughout the autumn, winter, and spring, and in the case of the Athabasca River they may continue throughout the summer. The variations in the Peace River during the three cooler seasons account for less variance and are not related particularly to the variations in runoff that occur in the last four months of the water year.

The second eigenvector has highest loadings for summer and early autumn, late in the water year. The loading for May indicates an earlier beginning in the summer component for the Athabasca drainage, which may be attributed to the lower elevation for large portions of the watershed and to the more southerly location of the drainage system. The inverted and smaller loadings for winter indicate an opposite but smaller variation during winter. This may reflect the delay in winter runoff that occurs in cold years, when the moisture is held in the watershed as snow. The third eigenvector accounts for more variance on the Peace River and differs between the two rivers in its weighting of the late autumn flow versus early spring.

In conclusion, the eigenvectors show distinct differences in the flow regimes of the two river systems especially for the summer season. These different flow regimes interact in a complex manner through the hydrologic system of the Peace-Athabasca delta area to control the levels of Lake Athabasca.

GROWTH PATTERNS IN THE PEACE-ATHABASCA DELTA AREA

Eigenvectors were also extracted from the correlation matrix of the six delta chronologies for the period 1810-1967. These eigenvectors describe orthogonal modes of occurrence which indicate a relative dependence among the chronologies. They are arranged in descending order of the percent variance accounted for in the original data. Fig. 5 shows the first five modes of dependence within the six chronologies, which accounts for a total of 97% of the variance. The first eigenvector is by far the most important. It accounts for 61% of the variance, indicating the large amount of ring-width variation that is common to all sites. The sign of the weights indicates that trees on all sites are positively correlated. The second most common growth pattern occurs 14% of the time. It groups the Quatre Fourches, Athabasca River, and Revillon Coupé sites and the Claire River, Peace River I, and Peace River II sites. The former set of sites has the highest loading on the Athabasca River site, suggesting a relationship to the Athabasca runoff regime, while the latter set are sites near the Peace River and probably represent its regime. The third eigenvector accounts for 10% of the variance and basically contrasts the growth on the Athabasca River site with the growth on the Revillon Coupé site. The fourth and fifth eigenvectors are less important

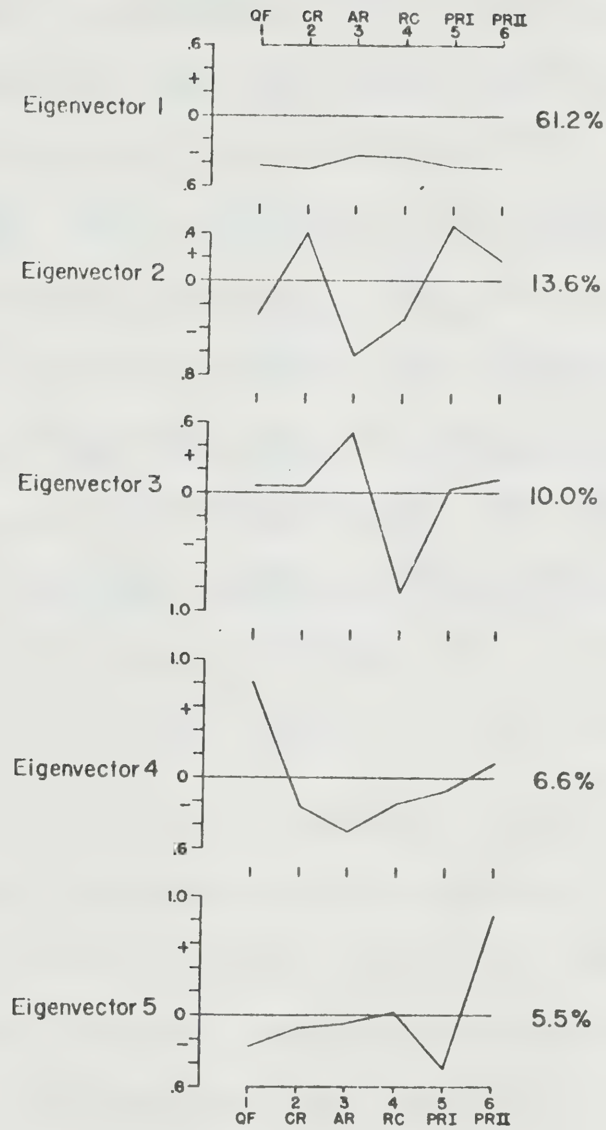

Figure 5. Eigenvectors for the correlation matrix of the 6 tree-ring sites in the Delta area showing relative dependence among the series.

and may represent orthogonality constraints.

Three major orthogonal components are apparent in the tree-ring data: (1) a common variation among all six sites, (2) a contrast of variation in sites near the Peace River versus those near the Athabasca River, and (3) a contrast between the Athabasca River and the Revillon Coupé. All three types seem to represent conceivable hydrologic situations that may result from differences in the inflow and outflow regimes. However, variations in the growth at the sites might also result in part from different limiting conditions and different lags in the growth response that could result from the same flooding regimes. The presence of such differences seems evident in the canonical regression results.

CALIBRATION OF TREE GROWTH AND WATER LEVELS

Water level data for Lake Athabasca, measured at Fort Chipewyan, were checked for completeness and 10-day means were calculated for the periods May 21-30, July 11-20, and September 21-30 (Table 3) by J. R. Card, Water Resources Division, Alberta Department of Agriculture. These data are used in the analysis that follows. During the May period water levels are rising, in the July period they are near their maximum, and during the September period they are usually receding. These three sets of water level data (spring, summer, and autumn) provide information on the earliness and lateness of flooding as well as the maximum water level for the year.

In this study, ring-width indices for the six Peace-Athabasca sites were used as predictors (independent variables) in a canonical analysis. The index value during the year concurrent with the measured water level (t) and during the subsequent year (t+1) were used, giving a total of 12 predictor variables. The statistical model is of the form ${}_3Y_t = {}_3B_{12}\ X_t$ where the matrix ${}_3Y_t$ has three variables $Y_{1,t}$, $Y_{2,t}$, $Y_{3,t}$ and X is a matrix of 12 variables $x_{1,t}$, $x_{1,t+1}$, $x_{x,t}$, $x_{x,t+1}$, ..., $x_{6,t}$, $x_{6,t+1}$, where t represents the 33 years from 1935 through 1967. B is a matrix of regression weights associated with each of the predictor

Table 3. Historical 10 day mean water levels for Lake Athabasca for 1935-1970 (36 years) compiled by J. R. Card (A. D. A. W. P. D.). E designates stage records for Goldfields or Crackingstone Point were used to estimate missing data. G designates missing value estimated by manual interpolation.

LAKE ATHABASCA WATER LEVELS

Year	10 day mean May 21-30	10 day mean July 11-20	10 day mean Sept 21-30	Year	10 day mean May 21-30	10 day mean July 11-20	10 day mean Sept 21-30
1935	685.0 G	693.2 G	689.2 G	1953	683.75	685.87	683.49
1936	689.3 G	692.0 G	689.4 G	1954	684.98	690.6 E	688.5 G
1937	687.0 G	687.8 G	685.3 G	1955	685.0 G	688.09	685.35
1938	683.54	685.40	683.22	1956	684.26	686.95	684.38
1939	684.3 E	686.46	684.46	1957	684.90	686.69	685.93
1940	685.63	687.4 G	684.61	1958	686.70	688.25	684.7 E
1941	684.97	686.14	684.2 G	1959	683.8 G	687.6 E	685.39
1942	685.3 E	688.27	685.14	1960	685.14	690.34	688.51
1943	684.49	687.83	685.0 G	1961	685.1 E	688.28	685.20
1944	684.3 E	685.78	682.9 G	1962	685.76	690.44	688.82
1945	683.0 G	683.97	682.5 G	1963	687.52	689.27	686.49
1946	684.78	684.89	683.22	1964	685.25	689.97	688.87
1947	686.22	687.84	684.87	1965	686.69	690.50	688.00
1948	687.26	689.36	686.00	1966	685.74	688.52	687.63
1949	684.49	686.26	684.25	1967	687.07	690.28	686.90
1950	684.67	686.65	682.98	1968	684.76	684.62	682.9 E
1951	687.04	688.15	685.15	1969	685.93	684.55	682.66
1952	684.44	686.84	683.58	1970	684.07	684.75	682.50

Table 4. Canonical regression coefficients used in the water level reconstruction equation. The reconstructed values are obtained by multiplying the normalized tree-ring indices for the year concurrent with predicted water level (t) and successive to predicted water level (t+1) by their respective coefficients. (See text.)

	Sites											
	Quatre Fourches		Claire River		Athabasca River		Revillon Coupé		Peace River I		Peace River II	
Water Level Period	Predictor Variables											
	$x_{1,t}$	$x_{1,t+1}$	$x_{2,1}$	$x_{2,t+1}$	$x_{3,1}$	$x_{3,t+1}$	$x_{4,t}$	$x_{4,t+1}$	$x_{5,t}$	$x_{5,t+1}$	$x_{6,t}$	$x_{6,t+1}$
May 21-30	0.159	-1.536	1.500	-0.509	0.786	0.078	-0.980	0.566	-1.231	-0.330	0.480	1.648
July 11-20	0.028	-1.217	0.143	0.664	0.813	0.404	-0.421	-0.210	0.533	-1.459	-0.279	1.835
Sept 21-30	0.968	-1.389	-0.149	0.895	0.477	0.201	-0.488	0.201	0.509	-1.007	-0.601	1.271

variables of matrix X.

The canonical regression techniques used here are presented in mathematical detail by Glahn (1968) and essentially involve the solution of equation 18 in Glahn's article. This technique is analogous to multiple linear regression, in which one dependent variable (predictand) is related to a set of independent (predictor) variables for many observations, which in our case are years. However, canonical correlation analysis relates a <u>set</u> of dependent variables (y's) to a set of independent variables (x's), and canonical regression may allow a better prediction of each dependent variable from the corresponding set of independent variables because it takes into account the covariance in the dependent set.

In canonical analysis, the x's and y's are transformed to orthogonal variables, and the correlations between sets are maximized. Thus the relationships between the two groups of variables (water level measurements and tree-ring data from the six delta sites) are reduced to their simplest forms. However, the question remains as to whether the regression weights have any meaningful interpretation or whether they are artifacts brought out by mathematical manipulation. One test of significance is the canonical correlation and the percent variance accounted for at each step of the regression.

Another test is the physical reasonableness of the data. A third test is a check with independent data when predictions are made.

The canonical regression coefficients are presented in Table 4. The equation used is:

$$\hat{y}_{i,t} = b_{1,t}x_{1,t} + b_{1,t+1}x_{1,t+1} + b_{2,t}x_{2,t} + b_{2,t+1}x_{2,t+1} + \cdots + b_{6,t}x_{6,t} + b_{6,t+1}x_{6,t+1}$$

where $\hat{y}_{i,t}$ is the predicted lake level expressed in normalized form (i varies from 1 to 3 and t varies from 1 to 33), and $X_{i,t}$ are tree-ring indices normalized for the calibration period (1935-1967). The reconstructed values, $\hat{y}_{i,t}$, are "denormalized" by multiplying by the sampled standard deviation for y_i during the calibration period and adding the corresponding sample mean.

Predicted water levels for Lake Athabasca were computed for the period 1935-1967 (33 years) and were compared to the actual values (Table 3). They were found to account for 57% of the variance in the actual values for May 21-30, 80% for July 11-20, and 79% for September 21-30. These values along with the corresponding reconstructed values for the period 1810 to 1934 are included in Appendix II. Figure 7, a plot of the reconstructed water level record for the period 1810 to 1967, also shows the actual recorded values as given in

Table 3.

The regression coefficients (Table 4) were plotted (Fig. 6) so that the final weightings within the prediction equation could be compared.

Regression weights for the six sites appear consistent with the site location within the hydrologic system. Quatre Fourches trees are on an apparently poorly drained soil and growth response is inverse to and lags behind the water level. Revillon Coupé growth is also inversely related to water level. The Athabasca River site is well drained and is positively related to lake level, indicating that high soil moisture favors growth. The Claire River site is also well drained and on an outflow channel exhibiting a delayed response. If the lake level is high early in the season, there can be high growth. If the lake level is high in mid or late season, it will in general affect the successive year's growth.

The Peace River I and Peace River II sites seem to act jointly in prediction of water level stages in the Peace-Rochers River system. For May 21-30, the lake level is not likely to be affected by flow of the Peace River. High lake levels are predicted if the growth at the Peace River I site is below normal (both in concurrent and successive years) but the growth at Peace River II is above normal. This could

stem from high outflow along the Rochers throughout the early summer, producing high growth at the Peace River II site when the growth at Peace I site is low. For both the July 11-20 and September 21-30 periods, the highest prediction of lake levels occurs when Peace River I and Peace River II sites show near normal growth inthe concurrent year but growth at Peace River I is below normal in the succeeding year while at Peace River II it is above normal. Flooding at this time is too late to affect growth, especially downstream at Peace River II site. High levels of the lake may cause high levels of outflow late in the year and produce better moisture conditions at Peace River II than at Peace River I where conditions of high water have subsided. As a result high photosynthesis may be favored at Peace River II and growth the following year may be higher than at Peace River I site. These results seem reasonable in terms of our present understanding but limited experience in the area. The specifics of the above discussion should be checked against flow records and measurements of soil and stand characteristics should be made.

The reconstructed water levels are plotted in Figure 7 in a manner analogous to a hydrologic trace, with actual measurements for the period 1935-1967 superimposed. The actual measurements are shown as dots and estimates of values missing

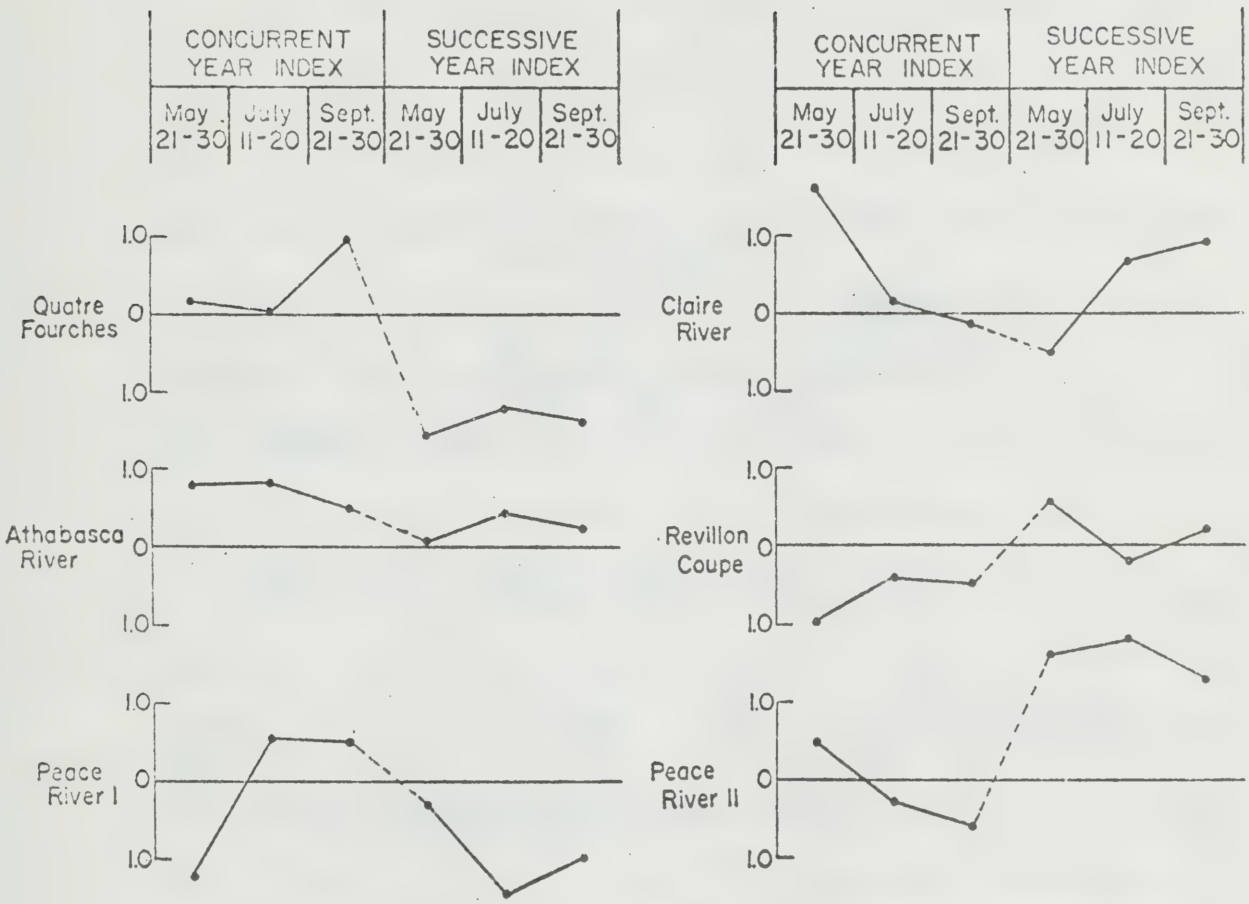

Figure 6. Plots of the coefficients in the prediction equation used to reconstruct Lake Athabasca water levels. A coefficient is associated with the three predicted periods and with the growth index concurrent with the predicted year, and with the growth index in the succeeding year.

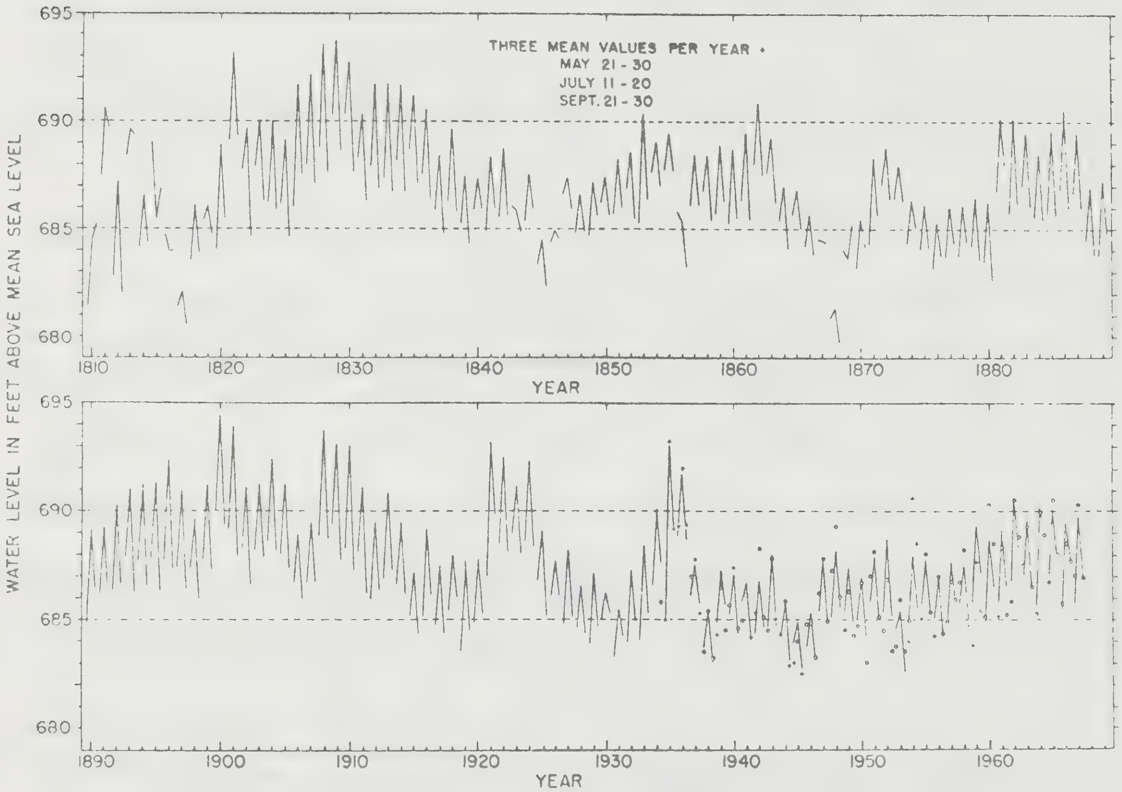

Figure 7. Reconstructed water level record for Lake Athabasca for the period 1810-1967 (158 years). These values were determined from tree-ring indices of the 6 Delta sites in which both the indices for the year concurrent with and successive to the actual runoff year were utilized as predictors. The actual values for 1935-1967 are also shown, where the circles indicate gauge measurements and the pluses indicate estimated values.

from the record are shown as pluses. The figure shows low levels centering around 1945, 1930, 1918, 1877, 1868, 1845, and 1887. The reconstructed record also indicates that periods of high water level were more common in the past than is indicated by the 33 years of record. Periods of high water level occur during 1921-1924, 1892-1913, and 1881-1887. High water levels are estimated for the years 1853 and 1862 and for the decade centering in 1830. In this early period prior to 1850 the number of usable trees declines and the error of estimate probably increases.

Table 5 shows the means and variances for the gauged record of 1935 through 1967, and for various periods of the reconstructed lake levels. Several pertinent points can be made about the changes of the mean and variance throughout time. The variance for July 11-20 for the over-all period 1810-1967 is almost twice the variance of water levels for the May or September period. This is in contrast to the data from the measured record, where the September variance is nearly the same as that for July. Both are about 2½ times the variance in May. The reconstructed record for 1935-1967 shows the same relationship as the actual record. This suggests that there may have been a tendency for more precipitation in late summer or early fall in the past 40 years than previously.

Table 5 Comparison of means and variances for actual record (Table 3) 1935-1967 and for various periods of the reconstructed record (figure 7).

Period	May 21-30		July 11-20		September 21-30	
	Mean	Variance	Mean	Variance	Mean	Variance
1935-1967[1]	685.38	1.82	688.06	4.31	685.58	4.11
1935-1967[2]	685.38	1.04	688.06	3.43	685.58	3.27
1810-1967	685.99	3.22	688.71	6.15	685.46	2.92
1810-1934	686.15	3.69	688.83	6.76	685.87	2.84
1810-1820	684.77	6.57	686.50	6.46	685.13	7.52
1821-1840	687.60	2.10	690.83	3.47	686.53	1.73
1841-1860	685.77	1.16	687.73	2.47	685.55	1.41
1861-1880	684.72	2.99	686.58	4.76	684.55	2.72
1881-1900	686.67	2.10	690.15	2.84	686.31	1.35
1901-1920	686.95	2.97	690.34	4.75	686.56	1.64
1921-1940	685.82	3.29	688.69	6.71	686.21	3.76
1941-1960	685.01	0.41	687.26	1.42	684.72	1.33

1. actual water level record from Table 3
2. water level record reconstructed from tree-ring data

Table 5 also shows the lowest mean for the May period to have occurred during the period 1861 to 1880, while second lowest value occurred during the period 1941 to 1960. The years of lowest variance about the mean for the dates May 21-30 are 1941 through 1960, with the period 1841 to 1860 being the second lowest.

The lowest 20-year mean appears to have occurred from 1810-1820 but this value is questionable because of diminished sample size. The mean for 1861 to 1880 was slightly higher, but there is less error in this mean. Third lowest 20-year mean period was 1941-1960 and was also the least variable 20-year period of water levels, followed by 1844-1860.

The reconstructed record for the dates September 21-30 indicates the mean level for 1841-1860 was one of the lowest for any 20-year period during 1810-1967. The period 1941-1960 was also quite low. The period 1881-1900 shows the least variation in water level for a 20-year period, with the variation in 1941-1960 being only slightly greater.

Records for all three periods, May 21-30, July 11-20, and September 21-30, reconstructed from tree-ring data indicate that during the 20 year sub-period 1941-1960 the lake levels were not only lowest but also exhibited low variances (i.e., they were consistently low) compared to the variances in other 20-year periods during 1810-1967.

The mean lake levels from 1810 to 1967 are not much different from those of existing record, 1935 to 1967. Variances, however, appear to have changed. A ratio of the variances for the entire reconstructed record and for the reconstructed record for 1935-1967 may be applied to the variance of the actual data. The ratio is used because a certain percentage variance is lost in the reconstruction. This procedure assumes that the percentage of variance lost in prediction is constant through time. However, this assumption may not be met in the early portions of the record because of the decreasing number of trees.

When these calculations are made, the variances (in feet^2) of the actual records, adjusted for the long-term records, become 5.62 for May 21-30, 7.71 for July 11-20, and 3.66 for September 21-30. This would indicate that the variance for May 21-30 during the short period of record is about 33% of what it should be based on the longer reconstructed record. The July 11-20 variance is about 60% of what it is in the longer record and the September 21-30 variance is about 110%. Adjustments for May and July probably stem from the low and extremely persistent water levels during the period 1941-1960 although they could be associated with such phenomena as climatic change and ice blockage, the latter being especially pertinent to the variance during May 21-30.

DISCUSSION

There are several limitations to the reconstruction techniques that must be kept in mind. The technique probably tends to average the true response to water levels over the entire delta area and consequently gives the average water level in the waterways from which the samples were obtained. For example, in one of the few documented historical accounts available, Petitot (1885, p.38) states that Lake Athabasca was dry from Four Forks to Bustard Island during 1879-1881. If the Bustard Island of which the Rev. Petitot speaks is the same as that known as Bustard Island today, then the levels shown on Figure 6 for 1879-1881 are low at the right place in time, but not low enough. The levels are about 3 to 5 feet (1 to 1.5 m) too high. Such discrepancies may be inherent in the tree-ring data themselves. However, it is assumed that the hydraulic connection between the lakes and delta waterways and the relationships between environment and growth have been consistent throughout time. There is some evidence that some of the channels have closed. The Athabasca-Embarras system could at times become more or less directly connected with the Quatre Fourches and Rochers channels. The results would be lower lake levels as compared to the tree-ring-recorded water level in the waterways. A check of the actual tree-ring indices for each of the sites

for 1879 and 1880 shows that growth at the Athabasca site was low, and in fact the ring-width index for 1879 is the sixth lowest value for the period 1768 to 1967 (200 years). The index value for 1879 for Peace River II, on the other hand, is 0.95, which is near average. The same holds for the Peace River I series. The values for 1879 in the Quatre Fourches, Claire River, and Revillon Coupé series are below average (near 0.70) but not grossly so. Consequently, the tree-ring values support the occurrence of a dry period but do not tend to support the extreme reduction in lake levels that Petitot describes, except for the very low growth at the Athabasca River site. Continued search of historical accounts may provide other independent checks.

The general low-frequency components within the reconstructed series are substantiated by tree-ring series from a much larger region. Comparison of tree-ring series outside the watershed area show comparable low-frequency trends, as does the reconstructed series shown in Fig. 7. Specifically, the long-term decrease in lake levels from 1900 to 1940 and an upward trend from 1940 to 1967 is present in other ring-width series and apparently represents a long-term climatic change. Edmonds and Anderson (1960) analyzed the climatic records from Fort Vermilion for 1909 to 1960 and found that there has been an increase in annual precipitation,

mostly winter precipitation, since 1909. During this same period, they noted that there has been a gradual rise in the mean annual temperature, totaling 3 Fahrenheit degrees (1.7 Celsius degrees). However, it appears that, at some time in the mid-forties, the temperature trend reversed and started downward. The general downward trend from 1870 to 1900 is also verified by the other widely dispersed chronologies. However, chronologies available to us at this time do not show as great a change during 1820 to 1840. This discrepancy could arise from the sampling error, as mentioned earlier. Additional tree collections should be made in the delta area and in the headwaters of the Peace River. Until more data can be obtained, the portion of the reconstructed series from 1810 to 1850 must be considered highly tentative.

CONCLUSIONS

1. The tree-ring series sampled in the Peace-Athabasca River delta appear to contain a strong signal concerning water-levels within the waterways. The relationships are both biologically and hydrologically reasonable.
2. Assuming that the relationships between water levels within the waterways and Lake Athabasca and the relationships to growth have been constant through time, the reconstructed water level record (Fig. 7) explains 57% of the actual variance for May 21-30, 80% for July 11-20, and 79% for September 21-30.
3 The reconstructed record (1810-1967) indicates that the May 21-30 lake levels have been 3 times more variable over the longer period than during the period of historical record (1935-1967). The July 11-20 levels have been more than 2 times as variable in the longer period, and the September 21-30 levels have been about 10% less than during the short period, 1935-1967.
4. The means for each of the 3 sub-periods of water levels for the period of historical record are very close to the mean for the long-term reconstructed record.
5. About the year 1967, the tree-ring data collected in the delta show a downward trend. For 1968, 1969, and 1970, the water levels during the period May 21-30 were

respectively 1.23, 0.06, and 1.92 feet (37.5, 1.8, and 58.6 cm) below the long-term average from the reconstructed water levels for the same dates. Water levels for July 11-20 were, for the same three years, 4.09, 4.16, and 3.96 feet (124.7, 126.9, and 120.8 cm) below the long-term average. Water levels for September 21-30 were respectively 2.56, 2.80, and 2.96 feet (78.1, 85.4, and 90.3 cm) below the long-term average.

6. The downward trend since 1967 in the tree-ring series appears to be both climatic and due to impoundment of water behind the W. A. C. Bennett Dam on the Peace River. It is noted in No. 5 above that the greatest departure from the long-term mean was in July, the period probably most affected by Peace River inflow into Lake Athabasca. Additional sampling in the upper watersheds of both the Peace and Athabasca Rivers will be necessary to fully determine the climatic effect.
7. According to the reconstructed lake levels, there has been only one other 3-year period from 1810 to 1967 when the lake levels were as low as that from 1968 to 1970, that being the period 1866-1868. The period 1942-1945 was nearly as low as during this early period.
8. Although the relationships and reconstructions from tree-ring indices appear highly promising, these results

should be further verified. Soil sampling, vegetational studies, and further hydrological calculations should be made to check the assumptions and observations mentioned in this preliminary report.

APPENDIX I

TREE-RING CHRONOLOGIES

QUATRE FOURCHES

ID 196740
MAP NUMBER 1

	TREE RING INDICES										NUMBER OF SAMPLES									
DATE	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1765						178	144	190	226	193						1	1	1	1	1
1770	163	140	92	94	77	106	65	43	42	61	1	2	2	2	2	2	2	2	2	2
1780	87	51	42	104	117	82	111	112	97	73	2	2	2	2	2	2	2	2	2	2
1790	55	95	55	34	50	36	55	50	41	64	2	2	2	2	2	2	2	2	2	2
1800	57	53	18	82	111	144	156	141	187	174	2	2	2	2	2	2	2	2	2	2
1810	200	203	155	199	131	121	99	104	119	102	2	2	2	2	2	2	2	2	2	2
1820	108	108	75	54	47	38	54	41	49	62	2	2	2	2	2	2	3	3	3	3
1830	60	80	67	94	88	91	93	93	95	98	3	4	4	4	4	4	5	5	5	5
1840	106	104	119	121	96	88	77	80	88	101	5	5	5	5	5	5	6	6	6	6
1850	101	112	123	133	122	129	104	115	114	123	6	6	7	7	7	7	8	8	8	8
1860	108	104	92	97	112	109	128	120	105	95	10	12	12	14	14	15	15	15	15	15
1870	98	118	98	107	108	116	89	121	107	73	18	19	19	19	22	22	22	23	23	23
1880	89	124	134	130	114	84	88	107	104	107	23	23	23	23	23	23	23	23	23	23
1890	109	95	93	83	74	84	77	79	90	96	23	23	23	23	23	23	23	23	23	23
1900	89	100	103	113	113	118	110	90	96	77	24	24	24	24	24	24	24	24	24	24
1910	85	107	89	82	97	76	72	76	102	115	24	24	24	24	24	24	24	24	24	24
1920	92	146	148	137	91	105	103	109	46	52	24	24	24	24	24	24	24	24	24	24
1930	95	88	127	120	152	176	153	142	94	74	24	24	24	24	24	24	24	24	24	24
1940	63	23	58	32	40	20	40	67	73	94	24	24	24	24	24	24	24	24	24	24
1950	45	56	32	45	64	52	101	106	138	164	24	24	24	24	24	24	24	24	24	24
1960	152	132	137	175	171	184	170	135	169	129	24	24	24	24	24	24	24	24	24	24
1970	93										24									

CLAIRE RIVER

ID 203749
MAP NUMBER 2

	TREE RING INDICES										NUMBER OF SAMPLES									
DATE	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1760	57	74	91	70	99	117	105	124	108	134	1	1	1	1	1	2	2	2	2	2
1770	88	90	90	96	88	105	98	97	95	88	2	2	2	2	2	2	2	2	2	2
1780	98	101	109	124	121	125	111	99	90	114	2	2	2	2	2	2	2	2	2	2
1790	94	115	93	100	109	86	122	107	102	123	2	2	2	2	2	2	2	2	2	2
1800	100	109	105	111	133	120	141	131	98	87	2	2	2	2	2	2	2	2	3	3
1810	88	88	75	70	65	68	60	66	69	67	4	4	5	5	6	9	9	10	10	10
1820	65	81	86	81	87	77	77	93	88	89	11	12	12	12	12	12	12	12	12	13
1830	92	111	123	125	117	103	108	103	91	94	14	14	14	14	14	14	14	14	15	15
1840	98	108	121	111	115	121	90	115	118	129	15	15	15	15	15	15	15	15	15	15
1850	145	143	164	136	102	120	119	114	115	111	15	15	15	15	15	15	15	15	15	15
1860	114	107	78	94	112	92	118	105	111	61	15	15	15	15	15	15	15	15	15	15
1870	100	117	104	110	112	114	80	90	77	61	15	15	15	15	15	15	15	15	15	15
1880	66	75	96	87	69	56	64	71	77	81	15	15	15	15	15	15	15	15	15	15
1890	70	75	78	83	84	95	74	93	94	94	15	15	16	16	16	16	16	16	16	16
1900	110	133	125	115	124	129	125	113	126	101	17	17	17	17	17	17	17	17	17	17
1910	109	110	74	82	94	81	81	98	99	113	17	17	17	17	17	17	17	17	17	17
1920	63	164	124	113	96	111	113	128	70	82	17	17	17	17	17	17	17	17	17	17
1930	116	115	132	108	120	130	142	121	97	75	17	17	17	17	17	17	17	17	17	17
1940	113	126	77	53	52	38	40	54	54	73	17	17	17	17	17	17	17	17	17	17
1950	52	66	57	69	65	78	122	109	144	142	17	17	17	17	17	17	17	17	17	17
1960	120	120	118	170	155	221	185	188	208	175	17	17	17	17	17	17	17	17	17	17
1970	132										17									

ATHABASCA RIVER

ID 205749
MAP NUMBER 3

TREE RING INDICES

DATE	0	1	2	3	4	5	6	7	8	9
1708									89	92
1710	94	112	97	99	100	93	91	94	109	87
1720	113	98	104	110	78	98	98	89	124	131
1730	137	143	146	156	117	112	101	103	123	115
1740	75	106	112	89	83	96	102	88	110	96
1750	132	104	115	105	113	113	103	86	71	98
1760	92	111	120	101	99	138	107	105	113	108
1770	105	91	84	90	82	98	72	93	100	123
1780	99	83	114	129	100	103	103	115	83	86
1790	63	102	81	60	99	114	138	129	75	109
1800	97	121	117	82	111	121	130	94	78	96
1810	100	132	161	148	75	70	114	95	109	102
1820	100	109	108	109	64	103	90	102	115	98
1830	94	97	115	109	109	94	113	79	93	92
1840	84	75	91	76	54	69	38	74	71	86
1850	79	94	112	114	108	81	88	78	113	119
1860	102	101	91	100	91	70	78	49	64	46
1870	80	93	110	101	120	122	76	111	66	47
1880	77	93	133	138	86	85	103	108	123	102
1890	79	86	42	81	86	79	107	74	60	69
1900	92	135	125	104	134	120	103	86	97	117
1910	115	157	117	122	110	97	113	99	125	108
1920	97	130	152	134	100	141	94	110	85	105
1930	111	79	115	134	159	178	156	91	46	53
1940	60	97	71	69	67	50	46	87	98	108
1950	81	94	85	63	73	79	99	99	129	146
1960	128	104	126	173	125	148	107	118	117	152
1970	130									

NUMBER OF SAMPLES

0	1	2	3	4	5	6	7	8	9
								1	1
1	1	1	2	2	2	3	3	3	3
4	4	4	4	5	5	5	6	6	6
7	7	8	8	10	11	13	13	13	13
13	13	13	14	14	15	16	16	16	16
16	16	16	16	16	16	16	16	16	16
16	16	16	17	17	17	17	17	17	17
18	18	18	18	19	19	19	19	19	19
19	19	19	19	19	19	19	19	19	21
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21	20	20	20	20	20	20	20	20	20
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20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20									

REVILLON COUPE

ID 207749
MAP NUMBER 4

TREE RING INDICES

DATE	0	1	2	3	4	5	6	7	8	9
1783				96	90	100	129	80	87	100
1790	117	107	140	129	103	65	48	87	104	67
1800	89	60	97	43	123	114	82	134	134	154
1810	136	138	165	78	119	88	252	272	191	128
1820	158	114	107	57	68	72	74	68	86	73
1830	101	124	127	133	93	88	100	97	84	69
1840	65	101	110	97	92	108	75	97	135	149
1850	149	162	152	148	109	144	162	154	144	153
1860	132	108	67	101	131	104	132	106	125	59
1870	137	134	95	130	171	147	109	133	116	76
1880	78	59	133	108	87	60	61	59	70	45
1890	38	28	36	35	27	36	39	38	50	67
1900	71	104	97	91	111	111	99	86	95	77
1910	89	91	77	80	101	84	82	76	83	115
1920	58	99	125	108	96	136	105	140	69	96
1930	108	124	148	126	123	165	119	147	105	75
1940	70	77	54	52	53	42	63	88	100	139
1950	88	99	93	90	95	87	142	116	145	134
1960	141	113	124	172	140	178	157	123	125	121
1970	91									

NUMBER OF SAMPLES

0	1	2	3	4	5	6	7	8	9
			1	1	1	1	1	1	1
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19	19	19	19	19	19	19	19	19	19
19	19	19	19	19	19	19	19	19	19
19									

PEACE RIVER 1

ID 208740
MAP NUMBER 5

DATE	TREE RING INDICES 0	1	2	3	4	5	6	7	8	9	NUMBER OF SAMPLES 0	1	2	3	4	5	6	7	8	9
1804					67	85	77	40	68	104					1	1	1	1	2	3
1810	97	83	72	75	73	65	56	59	74	76	3	3	4	4	6	6	6	6	7	8
1820	97	60	61	100	120	104	111	92	77	83	8	10	11	12	12	14	14	14	15	15
1830	80	114	122	115	105	98	116	103	92	101	15	15	15	15	15	15	15	15	16	16
1840	110	125	119	91	123	115	73	119	142	139	16	16	16	16	16	17	17	18	18	18
1850	124	132	154	152	86	102	99	101	114	118	18	18	18	18	19	19	19	19	19	20
1860	108	95	75	89	108	95	122	100	106	66	20	20	20	20	20	20	20	20	20	[illegible]
1870	115	129	114	122	124	143	122	134	111	96	20	20	20	20	20	20	20	20	20	20
1880	96	108	102	75	74	61	50	63	74	101	20	20	20	20	20	20	20	20	20	20
1890	95	93	84	75	67	103	97	105	91	89	20	20	20	20	20	20	20	20	20	20
1900	96	111	78	75	90	97	94	82	100	79	20	20	20	20	20	20	20	20	20	20
1910	85	84	62	69	73	64	74	84	97	117	20	20	20	20	20	20	20	20	20	20
1920	65	117	91	83	68	97	109	124	68	87	20	20	20	20	20	20	20	20	20	20
1930	117	134	154	130	152	177	139	109	93	49	20	20	20	20	20	20	20	20	20	20
1940	67	65	80	60	56	42	53	72	77	57	20	20	20	20	20	20	20	20	20	20
1950	49	67	67	63	67	72	97	99	120	170	20	20	20	20	20	20	20	20	20	20
1960	141	133	126	168	186	214	187	171	176	145	20	20	20	20	20	20	20	20	20	20
1970	90										20									

PEACE RIVER 2

ID 209749
MAP NUMBER 6

DATE	TREE RING INDICES 0	1	2	3	4	5	6	7	8	9	NUMBER OF SAMPLES 0	1	2	3	4	5	6	7	8	9
1698									51	51									1	1
1700	60	52	45	57	65	76	64	80	74	67	1	1	1	1	1	1	1	1	1	1
1710	54	59	50	57	76	66	66	79	101	101	1	1	1	1	1	1	1	1	1	1
1720	129	118	137	106	95	115	114	99	127	129	1	1	1	1	1	1	1	1	1	1
1730	133	126	136	93	121	111	107	96	105	95	1	1	1	2	2	2	2	2	2	3
1740	107	109	94	135	116	112	114	95	96	81	3	3	3	3	3	3	3	3	3	3
1750	94	91	100	101	121	114	103	86	70	64	3	3	3	3	3	3	3	3	3	3
1760	51	47	45	32	53	64	55	69	75	79	5	5	5	5	5	5	5	5	5	6
1770	75	72	67	79	67	98	90	102	106	95	6	6	6	6	6	7	7	7	7	7
1780	121	[illegible]	121	128	129	103	129	128	96	114	7	7	7	7	7	7	7	7	9	9
1790	84	126	91	92	112	92	103	97	86	113	9	9	9	10	10	10	10	10	10	10
1800	122	111	99	101	142	128	114	80	48	29	10	10	10	11	11	11	11	11	11	11
1810	66	[illegible]	127	109	105	107	85	98	98	95	11	11	11	11	11	11	11	11	11	12
1820	98	150	122	93	96	96	83	87	83	114	12	12	12	12	12	13	13	13	13	13
1830	124	155	118	128	123	112	131	115	102	111	13	13	14	14	14	14	14	15	15	15
1840	93	103	122	111	103	108	54	88	119	121	15	15	15	15	15	15	15	15	15	15
1850	112	126	139	137	113	128	132	108	135	123	15	15	15	15	15	15	15	15	15	15
1860	111	96	94	118	126	106	132	107	97	36	15	15	15	15	15	15	15	15	15	15
1870	85	107	96	111	113	109	82	108	94	95	15	15	15	15	15	16	16	16	16	16
1880	103	104	123	102	97	85	80	98	83	66	16	16	16	16	16	16	16	16	16	16
1890	69	92	96	111	102	112	107	116	118	119	16	16	16	16	16	16	16	16	16	16
1900	127	151	113	101	112	121	114	81	102	118	16	16	16	16	16	16	16	16	16	16
1910	114	114	66	65	88	75	53	68	69	84	16	16	16	16	16	16	16	16	16	16
1920	55	109	130	120	104	131	101	105	49	46	16	16	16	16	16	16	16	16	16	16
1930	75	80	111	100	118	148	136	130	111	64	16	16	16	16	16	16	16	16	16	16
1940	72	68	42	31	54	22	40	66	81	79	16	16	16	16	16	16	16	16	16	16
1950	54	61	55	73	63	74	99	91	108	136	16	16	16	16	16	16	16	16	16	16
1960	124	119	125	162	153	176	158	135	141	110	16	16	16	16	16	16	16	16	16	16
1970	74										16									

PATRICIA LAKE

ID 055540
MAP NUMBER

TREE RING INDICES

DATE	0	1	2	3	4	5	6	7	8	9
1730	125	64	137	170	133	139	105	63	158	85
1740	78	55	84	79	29	72	67	101	81	131
1750	65	68	126	135	106	131	83	25	36	46
1760	39	52	118	110	109	90	106	129	123	91
1770	84	48	56	71	59	111	69	50	118	82
1780	61	112	120	136	160	129	219	225	138	176
1790	73	114	82	25	67	112	74	87	71	124
1800	51	154	89	62	102	134	135	134	75	83
1810	109	108	123	90	74	61	81	68	143	182
1820	104	119	175	95	89	90	116	74	81	149
1830	172	79	82	51	89	71	94	29	83	74
1840	93	90	80	82	90	133	140	67	89	95
1850	61	74	68	30	136	179	78	137	96	85
1860	76	72	87	93	95	75	114	117	106	39
1870	32	65	110	114	171	194	184	213	92	225
1880	135	162	156	147	87	81	110	115	120	62
1890	82	94	76	117	67	116	84	117	92	61
1900	102	125	124	86	144	117	70	109	87	106
1910	100	104	40	80	115	54	66	72	98	37
1920	54	75	55	52	48	53	72	50	94	32
1930	92	37	76	93	102	88	42	42	62	53
1940	48	38	80	66	86	66	53	51	103	136
1950	151	131	68	161	250	209	147	115	154	187
1960	270	89	150	148	167	252				

NUMBER OF SAMPLES

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4	4	4	4	4	4	4	4	4	4
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5	5	5	5	5	5	5	5	5	5
9	9	9	9	9	9	9	9	9	9
12	12	12	12	12	12	12	12	12	12
16	16	16	16	16	16	16	16	16	16
17	17	17	17	17	17	17	17	17	17
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20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20				

APPENDIX II

RECONSTRUCTED WATER LEVELS

FOR LAKE ATHABASCA (1810-1967)

IN FEET ABOVE MEAN SEA LEVEL

Year	Mean May 21-30	Mean July 11-20	Mean Sept. 21-30
1810	681.371	684.537	685.257
1811	687.486	690.644	689.678
1812	682.795	687.243	682.098
1813	683.411	689.714	689.363
1814	684.140	686.609	684.401
1815	689.061	685.474	686.835
1816	684.795	683.956	684.011
1817	681.400	682.113	680.581
1818	683.572	686.155	683.884
1819	685.432	686.096	684.753
1820	684.015	688.919	685.506
1821	689.191	693.187	689.274
1822	687.788	689.681	684.657
1823	687.695	690.333	686.347
1824	686.227	690.029	685.897
1825	686.185	689.182	684.631
1826	686.037	691.721	687.558
1827	687.978	692.183	687.071
1828	688.751	693.551	687.653
1829	690.264	693.771	688.610
1830	690.320	692.771	687.638
1831	688.274	690.346	686.318
1832	687.695	691.769	686.989
1833	687.391	691.727	686.797
1834	688.142	691.664	686.775
1835	688.566	691.206	687.178
1836	687.570	690.592	686.328
1837	685.867	688.434	684.892
1838	686.262	689.652	685.811
1839	685.268	687.499	684.314
1840	685.944	687.373	685.946
1841	684.953	688.368	685.954
1842	685.566	688.747	685.629
1843	686.052	685.885	684.834
1844	685.395	687.540	685.973
1845	683.363	684.524	682.353
1846	684.375	684.940	684.561
1847	686.622	687.412	685.892
1848	684.806	686.659	684.879
1849	684.700	687.178	685.610
1850	686.259	687.464	685.713
1851	685.755	688.312	686.057
1852	686.893	688.695	685.552
1853	685.290	690.431	686.422
1854	687.684	689.054	687.025
1855	687.800	689.483	687.732
1856	685.825	685.389	683.274
1857	686.137	688.471	686.147
1858	686.806	688.458	685.425
1859	685.757	688.927	686.313
1860	685.267	683.766	685.573
1861	686.352	689.507	685.493
1862	688.017	690.875	687.512

Year	Mean May 21-30	Mean July 11-20	Mean Sept. 21-30.
1863	687.038	689.266	686.241
1864	685.434	687.013	684.032
1865	685.684	685.848	685.306
1866	684.289	685.660	683.812
1867	684.558	684.479	684.381
1868	680.877	681.299	679.717
1869	684.041	683.608	685.201
1870	683.194	685.457	684.171
1871	684.272	688.360	685.662
1872	687.043	688.824	686.416
1873	686.426	687.936	686.297
1874	684.326	686.344	684.056
1875	684.025	686.103	684.046
1876	683.198	685.310	683.733
1877	683.675	686.027	684.364
1878	683.729	686.076	684.340
1879	684.140	686.435	683.540
1880	683.445	686.242	682.600
1881	686.754	690.131	687.996
1882	685.690	690.152	686.170
1883	686.896	689.453	686.030
1884	685.555	688.439	685.423
1885	685.661	689.569	685.608
1886	686.815	690.498	685.961
1887	686.652	689.433	685.831
1888	684.443	686.880	683.755
1889	683.696	687.216	684.737
1890	684.856	689.211	686.381
1891	686.121	689.322	686.007
1892	686.363	690.319	686.673
1893	687.863	691.006	686.227
1894	687.763	691.256	686.545
1895	687.831	691.344	686.348
1896	687.780	692.384	687.380
1897	687.447	690.974	686.433
1898	687.423	689.682	685.919
1899	687.786	691.241	687.322
1900	690.051	694.427	689.400
1901	689.191	693.946	687.983
1902	688.281	691.179	686.608
1903	688.202	691.257	687.912
1904	688.608	692.415	688.135
1905	688.017	691.279	687.399
1906	686.709	688.947	685.958
1907	686.737	689.537	686.746
1908	688.893	693.755	688.745
1909	689.443	693.116	687.751
1910	688.298	693.042	687.281
1911	688.148	691.098	686.244
1912	685.989	689.516	686.363
1913	686.925	690.366	687.303
1914	686.650	689.524	686.151
1915	685.168	687.153	684.364

Year	Mean May 21-30	Mean July 11-20	Mean Sept. 21-30
1916	685.150	689.206	686.192
1917	684.734	687.486	684.379
1918	685.404	687.987	686.044
1919	683.562	687.669	684.447
1920	684.827	687.740	685.261
1921	686.977	693.201	689.838
1922	688.469	692.480	688.106
1923	688.971	691.204	688.000
1924	688.619	692.295	688.377
1925	686.819	689.073	685.152
1926	686.117	687.730	686.103
1927	684.813	689.213	685.097
1928	684.633	686.544	684.342
1929	683.885	687.155	684.670
1930	685.107	686.264	685.298
1931	683.281	685.485	684.222
1932	683.986	687.304	684.987
1933	684.088	688.445	685.337
1934	685.594	690.185	687.553
1935	685.193	693.128	689.314
1936	683.822	691.705	688.772
1937	686.152	687.558	685.741
1938	683.736	685.376	683.098
1939	684.851	687.313	685.694
1940	685.220	687.073	684.406
1941	685.861	680.725	684.056
1942	684.374	686.756	684.652
1943	684.711	688.005	684.734
1944	684.212	685.830	683.175
1945	683.906	684.872	682.703
1946	683.653	685.310	683.227
1947	685.302	687.729	684.840
1948	685.117	688.208	685.537
1949	685.344	687.403	684.852
1950	685.019	686.908	684.234
1951	685.782	687.883	685.201
1952	685.376	688.703	685.171
1953	684.541	685.381	682.592
1954	685.034	687.917	685.494
1955	685.752	687.717	685.313
1956	685.004	686.911	684.277
1957	684.890	687.606	685.821
1958	685.737	687.410	684.936
1959	685.762	689.316	687.105
1960	684.874	688.621	686.467
1961	685.799	689.146	686.530
1962	686.789	690.554	688.036
1963	686.919	689.530	686.491
1964	685.616	690.087	689.205
1965	687.054	690.057	687.603
1966	685.245	689.425	687.782
1967	685.690	689.723	686.953

RECONSTRUCTED WATER LEVELS FOR LAKE ATHABASCA (1810-1967) IN FEET ABOVE MEAN SEA LEVEL BY ANALYSIS OF TREE RINGS

(Quote: From 1968 to 1971 there is an apparent change in regime. This is obvious in tree rings. This would adversley affect previous correlation. C. Stockton: University of Arizona)

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SECTION Q

PEACE-ATHABASCA DELTA PROJECT

GEOTECHNICAL STUDIES

REPORT NO. 1

24 JUNE 1971

E-2143

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APPENDIX A - Field Investigation

APPENDIX B - Laboratory Test Results

APPENDIX C - Site Photographs

APPENDIX D - Preliminary Construction Possibilities (Prepared by Peace-Athabasca Delta Project)

APPENDIX E - Drawings

1. INTRODUCTION

1.1 Authorization

R. M. Hardy & Associates Ltd. have been retained by Peace-Athabasca Delta Project to carry out preliminary site investigations at a number of locations within the Peace-Athabasca delta. Authority to proceed with the work was given verbally on 23 March 1971 and confirmed by letter of 31 March 1971. The work was to be carried out within the general concepts outlined in our letter of 15 March 1971 except that the scope of the work was to be limited to an assessment of the site characteristics as determined by field survey and airphoto interpretation. It was understood that this investigation would be directed toward determining soil and foundation conditions for feasibility studies, and further investigation would be required once more definite plans for controlling water levels were developed.

1.2 Scope of Work

The main purpose of the geotechnical studies was to determine the soil and foundation conditions at seven locations on important rivers and channels within the Peace-Athabasca delta. Originally eight locations had been included but it was subsequently decided that Location 1, on the Slave River north of the confluence with the Peace River, would not be included since it represents a major hydraulic structure and as such would be beyond the scope of the water

control program presently contemplated. The remaining seven locations to be investigated are shown on Drawing E2143-1 found as a fold-out at the end of this report.

The types of structures contemplated for control of water levels in Lake Athabasca and adjacent bodies of water are listed in Appendix D. The list of construction possibilities was prepared by the Peace-Athabasca Delta Project and has served as a general guideline for the site investigation. However, the scope of the work has been altered in discussions with staff of the Peace-Athabasca Delta Project. The scope of the work covered by this report is basically to determine site conditions of a more general nature.

One of the guiding principles for the site investigation has been to provide an assessment of the feasibility of constructing relatively simple structures using available materials suitable for construction during the forthcoming winter working season. Less attention has therefore been paid to the possibility of constructing elaborate structures at the locations despite the fact that they might provide better control over water surface levels.

1.3 Status of Work

The information contained in this report has been obtained by a field survey during the period April 26 to 30, 1971. A description of the extent of the field work is given in Appendix A. It was essential that the field information be supplemented by airphoto interpretation of the surficial

geology in the area of each of the sites and this work was carried out by Dr. L. A. Bayrock of the Research Council of Alberta. It was particularly fortunate that Dr. Bayrock had previously carried out an extensive survey of the surficial geology in the general area. Dr. Bayrock visited the various sites to be investigated on 27 and 28 April 1971 and prepared a report dated 3 May 1971 covering his site observations and his airphoto interpretation of the materials available at the site.

The data from the field work and a modest amount of laboratory testing is incorporated in this report and the results have been discussed with representatives of the Peace-Athabasca Delta Project on 11 June 1971. At that meeting there was considerable discussion on the types of structures which could be employed to control water levels and it was agreed that the report would make general observations on the geotechnical properties of the materials at the seven locations plus a more comprehensive treatment of a possible structure at Location 6 to control the water level in Lake Mamawi and to discuss the feasibility of diversion of some water from the Embarras River into Mamawi Creek.

2. SITE GEOLOGY

2.1 General Setting

The locations of the seven sites examined for this report are shown on Drawing E2143-1. They are found within the easterly portion of the deltas formed by the Peace and

Athabasca Rivers. The basic geology of the area has been covered in a paper by Bayrock and Root presented at the proceedings of the Peace-Athabasca Delta Symposium*. For the most part, the sites are located either in inactive areas of the delta or areas which are active only during the flood period. The channels and distributaries found in the region are largely formed by natural levees except in those areas where bedrock forms the abutments. All outcrops exposed at the locations examined are formed in Precambrian bedrock of granite or granite-gneiss. The area is extremely flat with the major relief provided by the Precambrian outcrops of heights up to 200 feet.

The following detailed descriptions summarize the surficial geology and geotechnical conditions found at the specific sites examined for water control structures.

2.2 Specific Site Locations

The following paragraphs outline the geotechnical data at the seven locations covered by this report. The sites are given the same location number as given on Drawing E2143-1 together with a further breakdown to indicate the specific location within the general area. For example, Location 2.1 is located within the general area of Location 2. The drawings covering the site information

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* Bayrock, L.A. and J.D. Root, 1971, "Geology and Geologic History of the Peace-Athabasca Delta Area: A Summary", Proceedings of the Peace-Athabasca Delta Symposium.

are included as Drawings E2143-2 to -15 at the end of this report.

2.2.1 Location 2 (Township 114, Range 67; E2143-2 & -3)

Locations 2.1 and 2.2 are found on the Rivière des Rochers. Both Location 2.1, located on the main river channel, and Location 2.2, located on a bypass channel, are flanked by high bedrock outcrops which provide excellent abutments, see Photos 2.1.2, 2.1.3, 2.1.4 and 2.2.1. The depth of the channel at any point is less than 20 feet and the presence of rapids infers a bedrock foundation in the channels, see Photo 2.1.1. Abundant bedrock outcrops are available for quarrying rock fill. Small deposits of sand and gravel are evident on the east bank of the main channel north of Location 2.1. A small deposit of outwash sand was found near the west abutment.

High-water marks are found well below the top of the rock banks and it is judged that overflow would not easily scour out a new channel around the structure.

Locations 2.1 and 2.2 are fifteen air miles north of Fort Chipewyan. Access to the two sites would likely be by barge during the summer months or by construction of a winter road through rough muskeg and bedrock terrain. The winter road would require several ice bridges to cross major drainage features in the area.

Both sides offer excellent characteristics for almost any type of water control structure. Available materials could be used to construct either rockfill weirs

or rockfill and gravel cofferdams for structures which require dewatering.

2.2.2 Location 3 (Township 114, Range 9; E2143-4 & -5)

Locations 3.1 and 3.2 are located approximately two miles apart on the Revillon Coupé. The sites are approximately fifteen air miles northwest of Fort Chipewyan. The sites were chosen where there appeared to be rock outcrops on both sides of the river channel. In general the Revillon Coupé is formed by natural levees except in those locations where bedrock has controlled channel formation. There was no evidence of rapids at either of these sites and the estimated channel depths are in the range of 30 to 45 feet. At both sections the east bank is composed of clay, silt and fine sand and it is likely that the river bottom is formed of the same materials. At Location 3.1 the channel is narrower than elsewhere on the Revillon Coupé as is clearly evident from Photo 3.1.1. This evidence suggests that bedrock forms both abutments. The silt bank on the east side is therefore expected to be a relatively thin veneer over bedrock.

In both cases a flood plain exists on the easterly side of the channel and any control structure proposed for these sites would have to be designed on the basis of protection against erosion for any flow greater than the flow which establishes the regime at this section. Erosion protection would have to be provided by concrete aprons, quarried rock or possibly soil cement. At Location 3.1 there is

evidence of a small amount of gravelly sand on the west abutment. This gravel would not likely be suitable for concrete aggregates but could be used for cofferdam or dam core material.

Site access would require constructing a nine mile road from the existing winter road to the southwest. This road would involve a major ice crossing over the Chenal des Quatre Fourches. The only other access would be by barge during the summer.

2.2.3 Location 4 (Township 113, Ranges 9 & 10; E-2143-6 & -7)

Locations 4.1 and 4.2 are located approximately three miles apart on the Chenal des Quatre Fourches. The sites are more than fourteen miles northwest of Fort Chipewyan. Both of these sites were chosen by air reconnaissance where it appeared that bedrock formed at least one abutment and the distance to the other abutment was as short as possible. At both of these locations bedrock cannot be considered likely in the river channel and the distance to outcropping bedrock on the northerly abutments is about one-half mile. Sandy silt levees and clayey silt deltaic flood plains make up the northerly river abutments. This material is easily eroded or scoured.

At Location 4.1 several small gravel pits are found within four miles to the southeast. There is adequate bedrock outcrop for rockfill within a mile radius of the west abutment. Access to the site would be by the winter road

which follows close to the channel or by barge in the summer.

At Location 4.2 there are a number of small gravel pits adjacent to the major bedrock outcrops, see Photo 4.2.5. In terms of gravel borrow this is one of the best sites observed during the field work.

2.2.4 Location 5 (Township 114, Range 68; E2143-9 to -13)

Seven sites have been examined at Location 5, roughly six air miles northwest of Fort Chipewyan. The general location of the sites are shown on Drawing E2143-8 and represent a number of alternative water control locations for the Rivière des Rochers. The sites are on the northernmost boundary of the active delta region and as a result high flow levels occur near the top of most levees. All levees are of clayey silt to silty sand composition and are very susceptible to river erosion. However at all the sites chosen there are bedrock abutments except for the north bank of Location 5.3 which has a 100 foot flood plain before bedrock is encountered.

The river channels are relatively wide (about 600 feet) and most have deep channels in the order of 30 to 50 feet. Locations 5.3 to 5.6 inclusive have narrower channels (less than 350 feet) and the channel depths are estimated to be less than 25 feet. At Location 5.5 it is likely that bedrock forms the river bottom.

Throughout the area small deposits of sand and gravel till and outwash deposits are present but their extent has not been determined by field exploration. There is ample bedrock available to serve as rockfill for the various sites.

Summer access across the active delta region is possible only by barge because of the soft and unconsolidated sediments. Winter roads however could be constructed on the east side of Rivière des Rochers with ice bridges required for all but Locations 5.5 and 5.6 No survey data was obtained at Locations 5.6 and 5.7 because of time limitations.

Conditions for relatively major water control structures are fair at nearly all of the sites in Location 5. The amount of gravel aggregate available, however, is small and it will be necessary to assume concrete aggregate being obtained from sources near Fort Chipewyan.

2.2.5 <u>Location 6</u> (Township 111, Range 8; E2143-14)

Location 6 is found on the outlet channel for Mamawi Lake near the cluster of buildings known as Dog Camp, see Photo 6.1.2. It is approximately eight air miles southwest of Fort Chipewyan. The area surrounding the site consists essentially of deltaic sediment topography with bedrock outcrops occurring immediately adjacent to the river, as shown on Drawing E2143-14. The south bank has a bedrock abutment and a bedrock island is located just slightly west of this abutment. The north bank is formed in clayey or

sandy silt with a major bedrock outcrop approximately 350 feet north of the bank. Bedrock is found just at the ground surface a short distance north of the bank and it has been inferred that bedrock may lie at shallow depths on this side of the channel. It has also been inferred that bedrock might lie at a relatively shallow depth across the channel bottom itself.

Ample bedrock is available for rockfill quarry but no substantial aggregate deposits were found from air or airphoto reconnaissance. Photo 6.1.5 shows an exposure of weathered bedrock.

There are no roads in the vicinity of this site and transportation would have to be by barge during the summer months or by winter roads over the delta area to the northeast. An ice bridge would be required across the Chenal des Quatre Fourches to the northeast.

2.2.6 Location 7 (Township 109, Range 10, E2143-15)

At Location 7 it is proposed to divert a portion of the Embarras River flow into Mamawi Creek and thence to Mamawi Lake. The natural slope of the terrain is to the north towards Mamawi Lake. The location could not be examined on the ground at the time of the field trip because both the Athabasca and Embarras Rivers were in high-flood. Both of the rivers were overflowing their banks and inundating the surrounding forested flood plain to a depth of two to four feet. Drawing E2143-15, taken from Dr. Bayrock's report, shows a number of the features that are evident in this area.

There is insufficient topographical information available to judge the extent of excavation required for the diversion of the Embarras River to the north. The route appears to traverse soft sediments of a phase of the Athabasca Delta which is active only at flood levels. From geologic evidence it is inferred that bedrock would be the Athabasca Sandstone and would lie at depths of 20 to 50 feet, with possibly a thin covering of glacial deposits just above the bedrock. The overlying sediments are likely to consist of mainly fine sand which is highly susceptible to erosion. It is possible that sufficient flow could be diverted from the Embarras River by construction of an off-channel structure on the outside of the bend where the Embarras River turns sharply to the east. The location of the diversion and a proper appreciation of the consequences of such a diversion must be determined by a careful assessment of the river regime behaviour.

The Athabasca River is in an unstable condition in the vicinity of Location 7. Dr. Bayrock suggested in his report that a natural cut-off may eventually occur at the location shown by circled number 3 on Drawing E2143-15. A considerable diversion of water was occurring at this location on 28 April 1971 as can be seen from Photo 7.1.2. A photo showing the general terrain north of the Embarras River is given in Photo 7.1.1. It is not unlikely that substantial changes in the location of the Athabasca River could occur within a five to twenty-five year period; changes

which would have a major effect on the water levels in the vicinity of Lake Claire, Mamawi Lake and even Lake Athabasca itself.

2.2.7 Location 8 (Township 108, Range 6; No Drawing)

Location 8 concerns itself with the problem of water level in Richardson Lake. At the time of the site inspection, with Mr. J. R. Card in attendance, it was understood that the problem was to provide a positive outflow from Richardson Lake at the time when walleye minnows ought to migrate to Lake Athabasca. One solution would have been to raise the water level in the lake by damming the two channels which interconnect with the Athabasca River. Examination of the banks of these two channels showed that they are formed entirely in fine sand and silt and any structure in this area would have to be constructed of concrete or wood or steel sheet piling since the local material would have a very low resistance to scour.

A second alternative was to direct the flow from Maybelle River in such a way that the flow of the river would be toward the easterly part of Richardson Lake and hence conduct the fish toward the two channels leading to the Athabasca River. This can be done by dredging along the east channel of the delta formed by the Maybelle River and by blocking the west channel shown in Photo 8.1.4.

The deltaic materials are composed of sandy silt and no suitable concrete or construction aggregate was found near the site. Fine to medium grained aeolian sand occurs

only a short distance to the south. Three or four miles to the east, ancient Lake Athabasca beaches may contain coarse sand. The nearest gravel deposit is on Goose Island about fifteen miles to the north.

3. MATERIAL PROPERTIES

3.1 General

The major foundation materials in the Peace-Athabasca delta can be divided into five broad groupings. These are: bedrock, alluvium, glacial deposits (drift), aeolian sand and organic terrain. At the sites investigated bedrock and deltaic alluvium make up the major materials present. Elsewhere over the routes that winter roads would have to be constructed are considerable portions of organic terrain in the form of bogs and swamps.

3.2 Bedrock

It is likely that the Athabasca Sandstone underlies the southern portion of the Athabasca delta but no outcrops are known either at Locations 7 or 8 in this area. To the north there are abundant outcrops of Precambrian granite and granite-gneiss. These outcrops have been strongly scoured by glacial action. Photos 5.1.2, 5.5.5 and 6.1.5 show typical exposures of the bedrock in vertical faces. Both the granite and granite-gneiss are hard and durable. The vertical exposures show joint spacings of one foot or so. Where the bedrock is not weathered it is likely that the joints are very tight and it would appear feasible to produce large rock sizes by controlled blasting. It may be

more difficult to produce a wide range of rock sizes in order to provide a relatively impervious fill or to prevent piping of fine material into rock fills constructed on alluvium. Trial blasting should therefore be contemplated before rock fill designs are completed.

3.3 Glacial Deposits (Drift)

Sand and gravelly sand glacial deposits are found at isolated locations in or near the Precambrian outcrops. Plates B-1, B-2 and B-3 show gradations which are typical of the various deposits which may be found. With processing, the material represented by the gradation on Plate B-3 would be suitable for concrete aggregate. The gravelly sand till and the coarse outwash (Plates B-2 and B-3 respectively) would be suitable for transition layers within rockfill dams but sufficient material for this use has not been proven.

3.4 Alluvium

The fine grained soils which make up the bulk of the Peace-Athabasca delta may be divided into two basic types: sandy silt forming the natural levees at the channel banks and clayey silt or silty clay which form the flood plains and deltas.

The deltaic deposits represent unfavourable foundation materials and both levee and deltaic deposits are probably too weak to carry rockfill structures more than five feet high.

Where fine grained alluvium makes up the bed of the rivers, to any appreciable depth, say more than three feet,

the feasibility of constructing rock weirs will be questionable due to the low bearing capacity of this material. It is also easily scoured and could pipe into rockfill unless a proper transition blanket is provided.

Organic silt is found both in the levee and deltaic sediments. The deltaic sediments will also contain random peat layers. In very old and inactive parts of the delta, such as at Location 7 north of the Embarras River, many old lakes have been overgrown with muskeg and peat of over three feet in thickness may be found.

3.5 Organic Terrain

Since most of the sites were chosen at locations where bedrock forms both abutments, there is very little organic terrain associated with the locations for proposed water control structures. However at Locations 3 and 4, it is to be expected that in addition to the forest litter found on the levees, there will be swamp and bog conditions in the flood plain. Over the routes to be traversed by winter roads, if required, there will be a large proportion (possibly as much as 95%) of the route over swamp and bog areas. Construction of proper roads would be prohibitive in cost and these areas must therefore be traversed when the surface materials are frozen or at locations where corduroy roads can be constructed.

3.6 Aeolian Sand

Large areas to the south of Township 109 are covered by aeolian sand dunes, for the most part stabilized

with vegetation. The deposits are medium to fine grained. The dunes are found immediately adjacent to Location 8 and about six miles south of Location 7.

3.7 Permafrost

The Peace-Athabasca delta is located in the fringe area of the southern discontinuous permafrost region. At the time of the field work the soil was frozen within a few inches of the ground surface and therefore no observation of permafrost could be made. It is likely that at the river channels the heat from the river will have dissipated permafrost for a considerable distance from the banks. However permafrost might be found on the sheltered side of rock outcrops and under the cover of peat or other heavy organic material in the flood plains.

3.8 Vegetation

There is heavy growth of trees along most of the levees and in some cases the trees reach a height of 100 feet or more. In the flood plains, bush and swamp vegetation are common. At Location 7 the cost of clearing is an important item in any cost estimate.

4. WATER CONTROL STRUCTURES

4.1 General

The study of the data now available leads to the inescapable conclusion that except where bedrock forms both abutments and can at least be reasonably inferred to form the river bed, it is not possible to plan any type of water control structure with a reasonable degree of certainty as to

design and feasibility. The study also leads to the conclusion that rockfill structures are the only means of water control that will be practical without extremely high costs. Except perhaps at Location 4.2 we have found no adequate sources of aggregates for the production of concrete or for the necessary transition zones required for rockfill placed on alluvium.

At Locations 2.1 and 2.2 on Rivière des Rochers, 3.1 on Revillon Coupé, 5.5 on the Rivière des Rochers, and possibly 6.1 on the outlet for Mamawi Lake, the evidence available suggests the strong possibility of bedrock forming nearly all of the river bed. Elsewhere it is almost certain that alluvium forms the river bed and for the rockfill or other water control structures, the strength of the alluvium is not sufficient to act as a foundation material - at least for normal construction procedures and rate of progress. This is not to say that suitable structures could not be located where there is no bedrock in the river bed but simply that until the types of structures required and together with the necessary hydrological and river regime data are provided, there are too many unknown factors to be considered before determining whether or not structures would be feasible.

At the meeting with officials of the Peace-Athabasca Delta Project on 11 June 1971, it was agreed that attention would be focused on the possibility of raising the water level in Lake Mamawi together with study of the diversion at

Location 7 in order to provide extra inflow into the Mamawi Lake drainage area. This is Alternative D outlined in the Preliminary Construction Possibilities in Appendix D.

4.2 Alternative D

There is reasonable evidence to suggest that bedrock forms at least part of the river bed at Location 6. It is certain that the south abutment is formed of bedrock and quite likely that bedrock will be found not far below the surface on the north abutment. Before design can be finalized, confirmation of these assumptions must be made by drilling in the field. It is likely that the rock island in the center of the channel should be employed as a part of any rockfill used to impede flow through the channel.

No source of gravel was found at Location 6 and the only available construction materials are either quarried bedrock or fine sand and silt that make up the river banks near the site. The suggested scheme is to place a rockfill dam across the channel with a diversion ditch on the north abutment within which there would be culverts gated on the west end in order to be able to permit flow coming from Lake Athabasca to pass into Mamawi Lake. It has been estimated that the dam should be sufficiently high to produce an extra three feet of water in Mamawi Lake. A fuse-plug type of spillway should be considered if there is a likelihood of overtopping the rockfill.

Since there is normally very little flow out of Mamawi Lake, the dam ideally should be watertight in order

to maintain as high a level of water as possible. We judge that quarrying the bedrock could be sufficiently controlled that a reasonable amount of fine material is created but it is unlikely that the resulting rockfill could have a permeability less than one or perhaps 1×10^{-1} centimeters per second (2 or 0.2 feet per minute). For this range in permeability and for a three foot differential head, the approximate amount of flow through a simple rock-fill dam would be between 15 and 1.5 cfs. However it is not possible to be sure of these minimum permeabilities and therefore something like 150 cfs should be considered as the more likely seepage loss.

To reduce seepage it would be possible to construct a dam with a central clay or silt core although construction of such a core in the winter time would be difficult. Other possible methods of reducing seepage through the weir would be the use of a grouted face on the Mamawi Lake side or possibly by simply dumping silt material on the upstream face to provide a self-sealing impermeable barrier. The fact that the total water head on the structure is not great is favourable to this type of design.

There is almost no information on the topography or materials at Location 7, the diversion from the Embarras River. There is little doubt that there is a considerable fall in ground surface to the north from the Embarras River and therefore it should be a simple matter to divert flow from the river into the drainage area of Mamawi Creek. The

most serious problem will be that of safely diverting water from the Embarras River without precipitating regression of the river to eventually cause a cut-off of the Athabasca River itself. The diversion ditch could be cut using a dragline operating on either frozen ground or swamp pads. We anticipate no difficulty in digging the necessary ditch and have shown on Drawing E2143-15 a possible take-off point for the diversion. A very careful evaluation of river behaviour would be required to establish the type of diversion take-off from the Embarras River in view of the very serious consequence of substantial changes in river regime either to the Embarras or to the Athabasca River. It is almost certain that any type of control structure would require a timber or concrete structure founded on piles together with bank protection provided either by sheet piling, timber cribbing or concrete pavement. Alternatives which might be considered for bank protection would be brush mats or some of the commercial membranes now being used for river control on the Mississippi and Arkansas Rivers. Once the basic scheme has been satisfactorily developed, it would then be necessary to drill test holes at locations of specific structures and to develop the necessary scour resistant control features.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The study completed to date provides general information on the materials available at the specific site locations within the limitations provided by overall costs and flood and

ice conditions prevalent at the time of the field work. With the information now available, it will be possible to appraise the feasibility of specific types of water control structures once the basic requirements for these structures are known.

5.2 Rockfill

Rockfill structures are the most obvious type of water control and considerable investigation has been made of their stability for certain assumed flow conditions. It became obvious that these studies could not continue further until more specific information was provided as to the crest height, river velocities, and the need for navigation openings. This information on fill stability is available in our files and will serve as a basis for further study when required.

Our preliminary conclusion is that rockfill weirs, with sufficient top width to permit dumping by trucks and with slopes at the angle of repose, will be satisfactory if the outside rock is sized to prevent erosion or ravelling and if steel reinforcement is used within the upper part of the fill. This design does not consider the river hydraulics associated with providing navigation or backwater effect.

5.3 Further Work

We understand that in the immediate future, investigation will be concentrated on Alternative D involving a dam or other structure at Location 6 and possibly diversion

from the Embarras River at Location 7. We believe that a dam can be placed at Location 6 but in order to prepare proper design details, it will be essential to determine the bedrock profile within the river channel and on the north bank. We also recommend that plans be developed for a test of the kind of rockfill that can be produced. The gradation will have a strong influence on the type of configuration. To this end it would be desirable to retain the services of a consultant specializing in blasting or to use the services of one of the manufacturers of explosives such as Canadian Industries Limited.

At Location 7 it is essential to develop the topography and assess river behaviour before route selection can be made and a general plan for diversion be established. Once this is done, it will then be necessary to carry out sufficient amount of test hole drilling to prove out the type of materials to be encountered and in particular at those locations where water control structures would be located.

Respectfully submitted,

R. M. HARDY & ASSOCIATES LTD.,

Per: MCHarris

M. C. Harris, P.Eng.,
Chief Engineer.

MCH/jl
E-2143

10214 - 112 Street,
Edmonton 12, Alberta.

June 24, 1971.

SECTION Q

APPENDIX A

Field Investigation

FIELD INVESTIGATION

The field work for this preliminary geotechnical report was carried out during the period 26 to 30 April 1971. The work was carried out in two phases. The first phase field party consisted of Mr. J. Card (PADP), Dr. L. A. Bayrock of the Research Council of Alberta, Mr. M. C. Harris and Mr. R. J. Bednar of R. M. Hardy & Associates Ltd.

The first phase of field work consisted primarily of viewing each of the proposed Locations from a helicopter (Bell 206A, Jet Ranger). These aerial observations were complemented by landings at selected points to confirm observations made from the air. During this phase Mr. Card explained in detail his concept of how proposed structures might function within the given setting at each location. Based on observations made concerning bedrock outcrops, several specific locations were selected for further examination. A number of soil samples were obtained from levees and granular deposits.

The second phase of field work was conducted by Mr. R. J. Bednar assisted by a technician from R. M. Hardy & Associates Ltd. and a rodman, who was employed locally. Work done during this phase concentrated on several specific locations selected during the first phase of field work. This work included surface profiles at proposed abutment locations, obtaining site photographs to accompany detailed notes describing conditions at each site. Additional samples

were taken of soil in the levees and potential granular deposits.

Data for surveyed surface profiles was obtained primarily by using a hand level in the immediate vicinity of each abutment examined. Where the distances involved were large, surface profiles were visually estimated, e.g. at the north abutment of Location 4.2. Elevations were referred to existing benchmarks where possible.

Soil samples were taken only from the surface as the ground was generally still frozen below a few inches.

No soundings were taken of river bottoms, as generally the channels were blocked with ice. Channel cross-sections shown on the drawings have been derived from data provided by Mr. Card. Apparently this data was obtained by the Water Resources Division, Department of Agriculture of Alberta in July of 1970.

The following table summarizes the extent of surveying carried out at each location. The letter subscript following the location number indicates the specific abutment, e.g. 2.1 W refers to the west abutment, Section 1, Location 2.

LOCATION SURVEY SUMMARY

Location No.	Aerial View Only	Ground Reconnaissance	Detailed Ground Survey
1	x		
2.1		2.1 E	2.1 W
2.2	2.2 W		2.2 E
3.1			x
3.2			x
4.1			x
4.2			x
5.1			x
5.2			x
5.3			x
5.4			x
5.5			x
5.6	5.6 W	5.6 E	
5.7	5.7 W		
6.1	6.1 S	6.1 N	
7.1	x		
8.1		x	

SECTION Q

APPENDIX B

Laboratory Test Results

LABORATORY TESTING

A limited amount of testing has been carried out on the surface samples obtained during the field investigation. Samples obtained by Dr. Bayrock are presently stored at the Research Council of Alberta. These latter samples have been only visually classified.

The following table summarizes the results of laboratory testing. The column headed "Landform" indicates the mode of soil deposition, e.g. till. The letter subscript following the location number identifies the abutment, e.g. 2.1(W) refers to the west abutment of Section 1 at Location 2. Grain size curves are included as Plates B-1 to B-3.

Soil types are designated by a modified version of the Unified Soil Classification System. Explanation of terms and symbols used in this report are included at the rear of this Appendix.

SUMMARY OF SAMPLING AND LABORATORY TESTING

Location No.	Sample No.	Landform	Atterberg Limits W_L	I_P	w	Grain Size	Unified Classification	Remarks
2.1.E	*LB-71-7-2	Outwash					(SP)	
2.1.E	LB-71-7-3	Outwash					(GP)	
2.1.S	3	Outwash	--	N.P.	14.7	B-1	SP	200' W. of bank
2.2.E	11	Deltaic Sediment	37.7	8.4	49.9		ML	145' offshore
3.1.W	2	Deltaic Sediment			38.0		(ML)	organic
3.1.E	8	Till	16.7	2.9	17.3	B-2	SM	1000' E. of bank
3.1.E	9	River bank			28.8		(ML)	
3.2.E	6	River bank	23.6	4.6	24.4		CL-ML	organic, sandy
4.1.E	4	Levee	26.7	3.2	30.8		ML	organic
4.2.N	10	River bank	27.3	2.7	19.8		ML	sandy
4.2.N	1	Levee	35.5	7.5	32.7		ML	organic
4.2.S	13	Outwash				B-3	GP	sandy, some cobbles
5.2.W	12	Alluvium	46.9	10.4	95.0		OL	W. of rock outcrop
5.3.N	5	River bank			34.6		(ML-CL)	organic
5.3.N	7	Till			31.1		CL-CI	400' N. of shore
5.6.E	*LB-71-6-5	Levee					(SM-ML)	
5.7.E	LB-71-10-2	Levee					(SM-ML)	
6.1.N	LB-71-6-1	Levee					(SM-ML)	
6.1.N	LB-71-5-2	Drift					(SP)	
8	LB-71-3-2	River bank					(SM-ML)	

* Samples stored at Research Council of Alberta

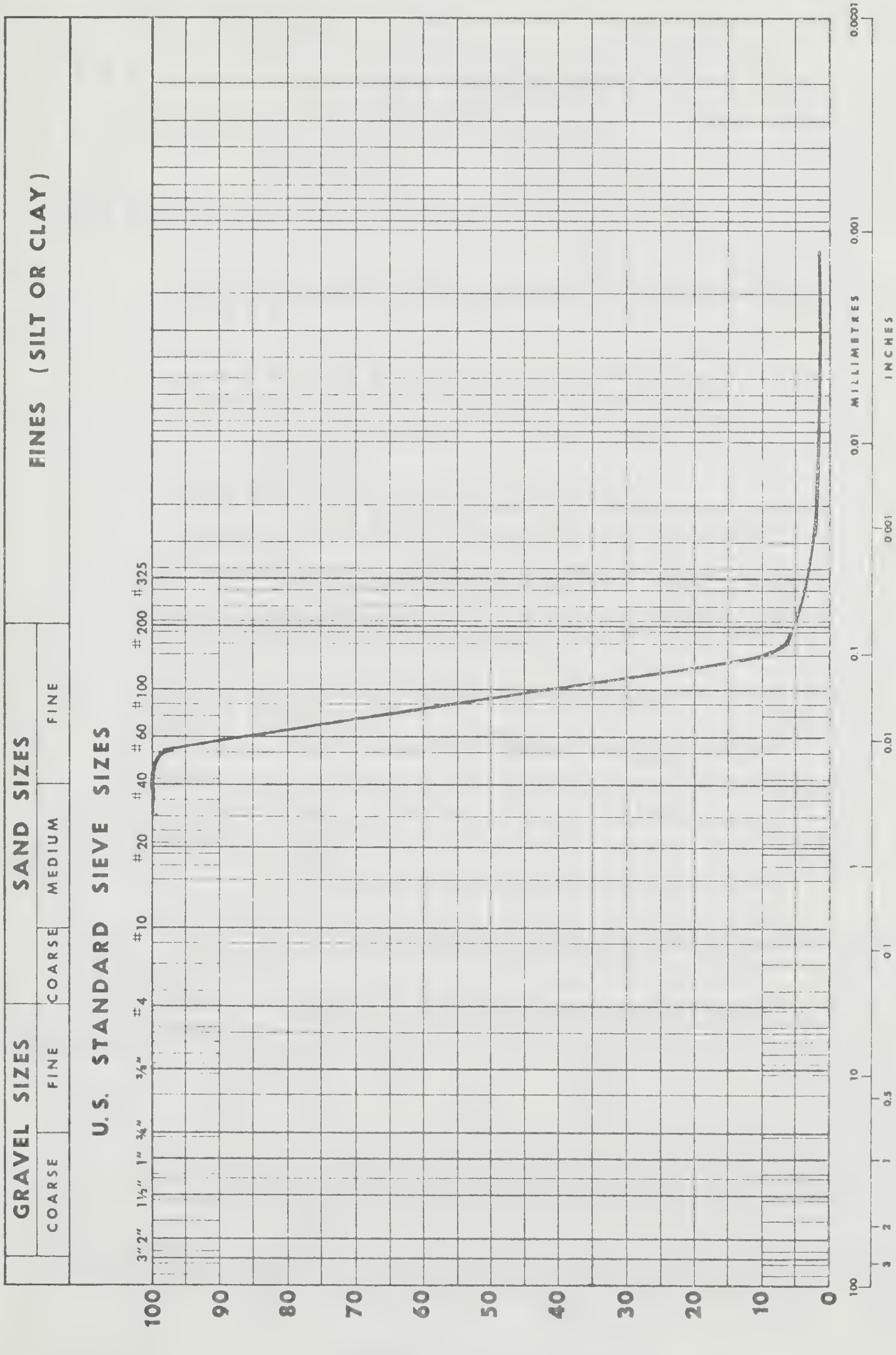
MTL–2–68

MAY 21 1971

MATERIALS TESTING LABORATORIES LTD.

GRAIN SIZE CURVE

LAB ORDER NO.	S676
CLIENT	E2143
SAMPLE	Sand
SOURCE	Location 2.1, S. Abutment
HOLE 3A	DEPTH 2-15 — DATE REC'D. May 71
TECHNICIAN G.P. & D.S.	DATE TESTED May 71



D_{10} = ____ MM.
D_{30} = ____ MM.
D_{60} = ____ MM.
C_U = ____
C_C = ____

REMARKS: Considered to be outwash deposit

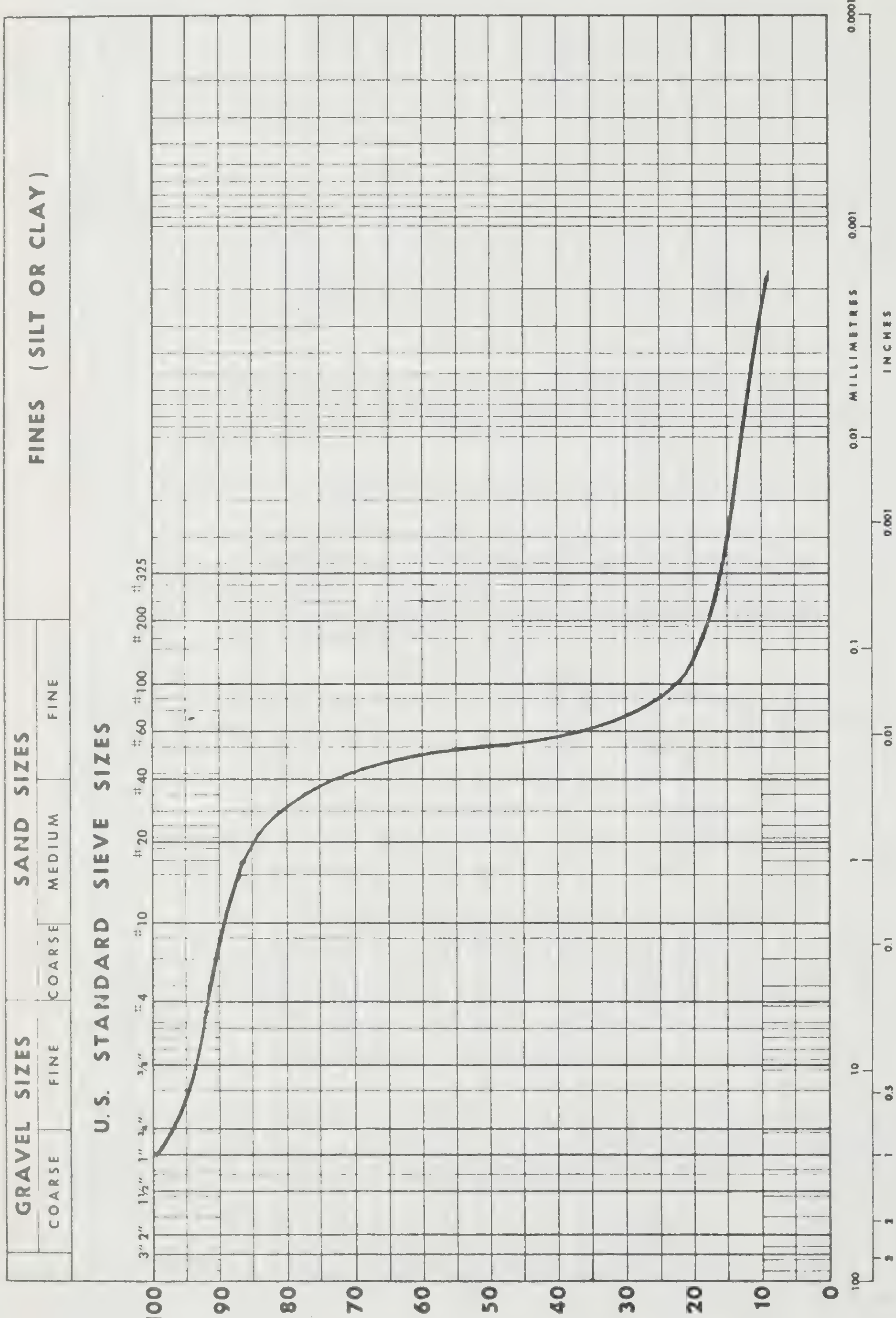
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

MTL-2-68

MATERIALS TESTING LABORATORIES LTD.

GRAIN SIZE CURVE

LAB ORDER NO.	S-676
CLIENT	E2143
SAMPLE	Gravelly Sand
SOURCE	Location 3.1, E. Abutment
HOLE 8 A	DEPTH ~~3+E~~ DATE REC'D. May 71
TECHNICIAN G.P. & D.S.	DATE TESTED May 71



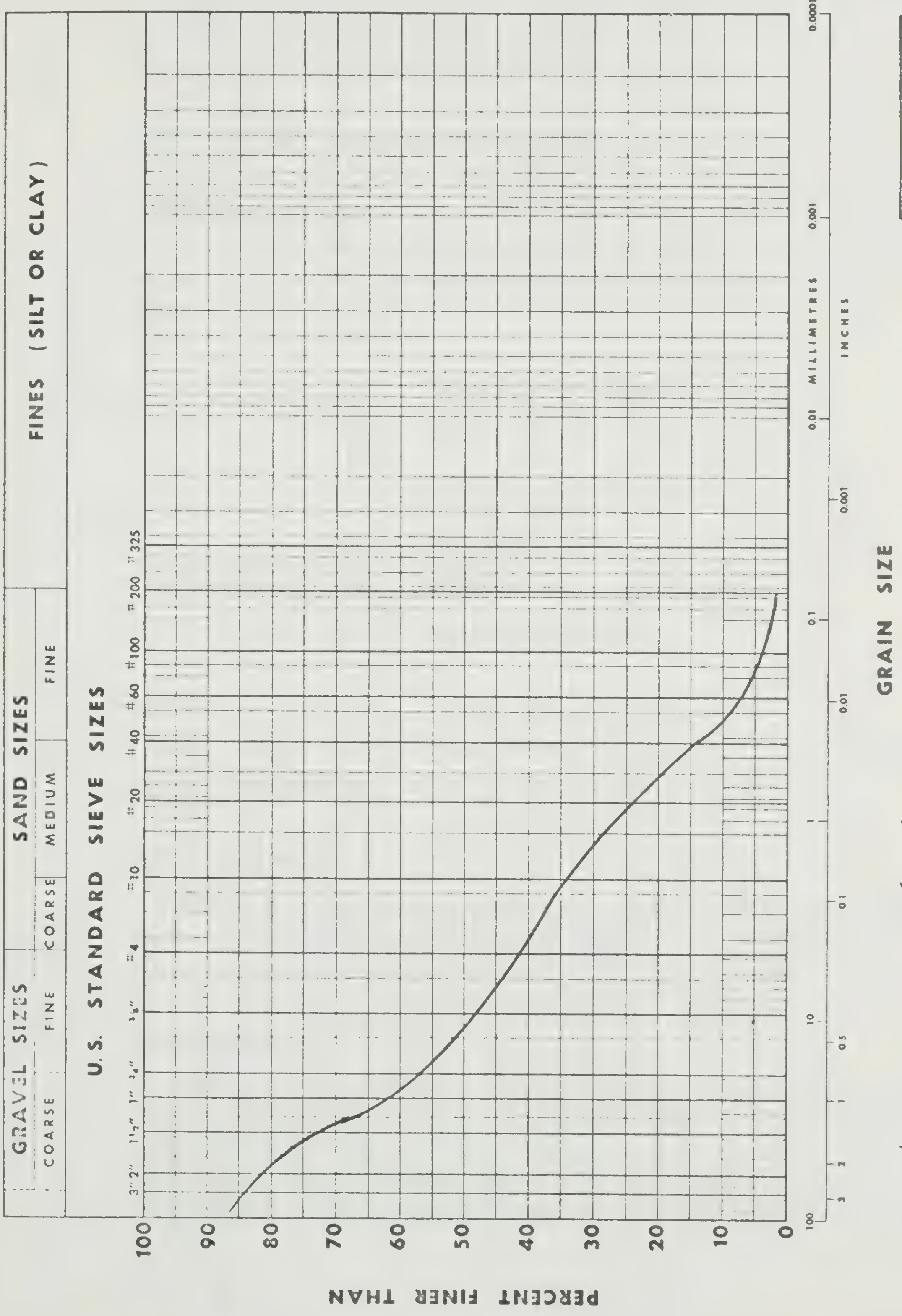
D_{10} = ____ MM.
D_{30} = ____ MM.
D_{60} = ____ MM.
C_U ____
C_C ____

REMARKS: Gravelly Sand Till

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

MATERIALS TESTING LABORATORIES LTD.
GRAIN SIZE CURVE

LAB ORDER NO.	S-676
CLIENT	E2143
SAMPLE	Pit Run Gravel
SOURCE	S.W. Corner of Rock Loc. 4.2
HOLE (") DEPTH	DATE REC'D. May 71
TECHNICIAN G.P.	DATE TESTED May 71



D_{10} = ____ MM.

D_{30} = ____ MM.

D_{60} = ____ MM.

C_U ____

C_C ____

REMARKS: Maximum size 5 inches

Outwash

See Photo 4.2-5

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

EXPLANATION OF TERMS AND SYMBOLS

These pages present an explanation of the terms and symbols used on the log sheet entitled "Summary of Sampling and Laboratory Tests". The materials, boundaries, and conditions have been established only at the test hole locations and could differ elsewhere on the site.

WATER CONTENT AND ATTERBERG LIMITS

The natural moisture or water content of the soil at the time of drilling is plotted against depth, together with the plastic and liquid limits whenever determined in the laboratory. All water contents are expressed in terms of percentage of dry weight. The abbreviations and graphic symbols are defined as follows:

⊙	w	natural moisture content
⊡	w_P	plastic limit (ASTM, D424)
△	w_L	liquid limit (ASTM, D423)
	NP	non plastic soil
——→		seepage
—▼—		observed water level

DEPTH

This column refers to the depth below the surface. The corresponding elevations are sometimes shown with respect to the datum given.

SOIL DESCRIPTION

Soils of different engineering classification are commonly grouped generically for ease of reference. Seepage and the water level are indicated beside the graphical representation using those symbols defined under "Water Content".

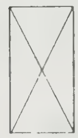
SOIL PROFILE

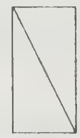
Soil types are designated by a modified version of the Unified Soil Classification System ("The Unified Soil Classification System", Technical Memorandum No. 3-357, Vol. 1, 1953, the Waterways Research Station, U.S.A.). Page 3 of this appendix defines these terms and symbols. Letters appearing in parentheses denote visual identifications which have not been verified in the laboratory.

SOIL SAMPLES

CONDITION — This column indicates the depth and the condition of each sample attempted.

 undisturbed

 disturbed

 not recovered or not retained

TYPE — The type of sample is indicated in this column as follows:

A	auger sample
B	block sample
C	rock core
D	drive sample
P	Pitcher tube sample
U	thin walled tube sample
W	wash or air return sample
O	other (see text)

PENETRATION RESISTANCE — Unless otherwise noted this column refers to the number of blows (N) of a 140 pound hammer dropping 30 inches required to drive a 2 inch O.D. open end sampler a distance of one foot from 0.5 to 1.5 feet into the soil. This is the standard penetration test referred to in ASTM, D1586.

RECOVERY — This column states the proportion in percent of the sampled length that was recovered. If nothing is shown the amount of recovery was not measured.

OTHER TESTS

In this column are tabulated results of all other laboratory tests as indicated by the following symbols:

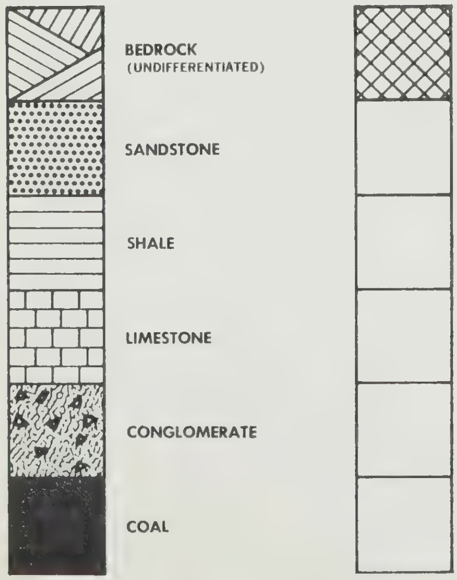
*	C	Consolidation test
	Fines	Fraction washing past #200 sieve
	G	Specific gravity
	k	Permeability coefficient
*	MA	Mechanical grain size analysis
	pp	Pocket penetrometer strength — tsf
*	q	Triaxial compression test
	qu	Unconfined compressive strength
*	SB	Shearbox test
	SO_4	Concentration of soluble sulphates
*	ST	Swelling test
	VS	Vane shear strength (undisturbed-remolded)
	ε_f	Unit strain at failure
	γ	Unit weight of soil (bulk density) — pcf
	γ_d	Unit dry weight of soil — pcf

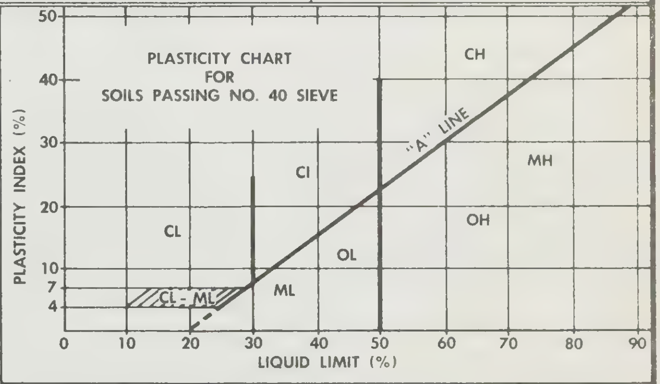
* These tests are usually summarized separately.

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6 \; C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4 \; C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	

SPECIAL SYMBOLS





1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.

RMH R. M. HARDY & ASSOCIATES LTD
CONSULTING CIVIL ENGINEERS
EDMONTON CANADA

SECTION Q

APPENDIX C

Site Photographs

Taken 27 to 30 April 1971

NOTE: The first two numerals in each photo number refer to the site location.

Photo 2.1.1
27 April 71
Looking SW towards
West abutment

Photo 2.1.2
27 April 71
East abutment

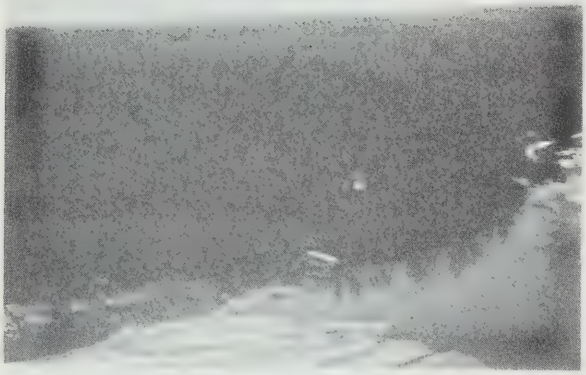


Photo 2.1.3
27 April 71
Looking West towards
West abutment

Photo 2.1.4
27 April 71
Looking NW
East abutment

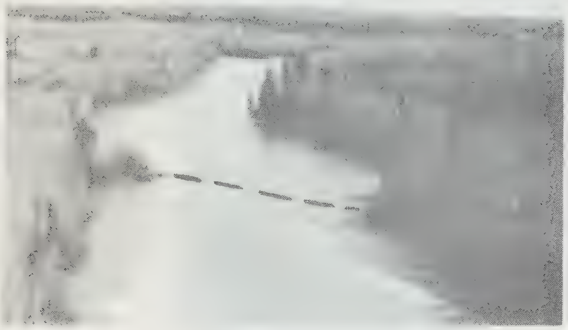


Photo 2.2.1
29 April 71
Looking SE

Dotted line indicates proposed location of structure.

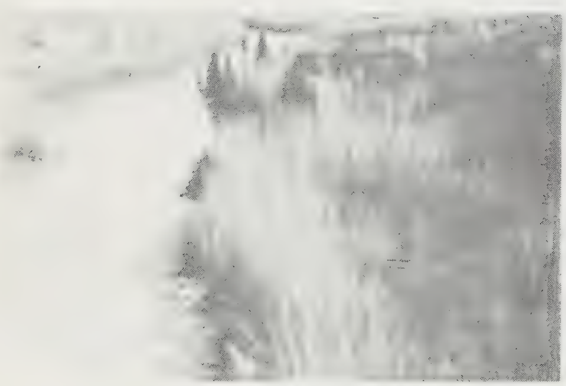


Photo 2.2.2
29 Apr 71
Looking ESE

Note marsh in right foreground.

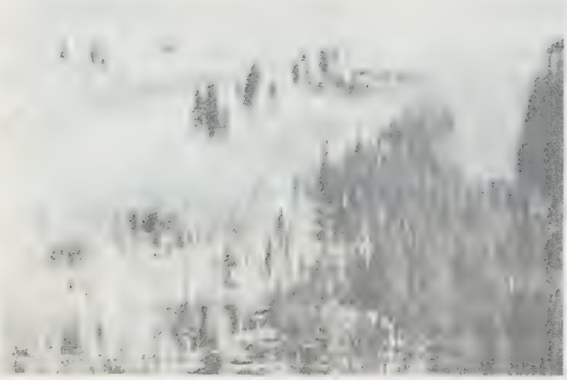


Photo 2.2.3
29 Apr 71
Looking East

E. abutment in left middle distance.

Note marsh in left foreground which is behind rock outcrop forming west abutment.

Photo 3.1.1
28 Apr 71
Looking NW

Photo 3.1.2
28 Apr 71
Looking SE
West abutment in foreground

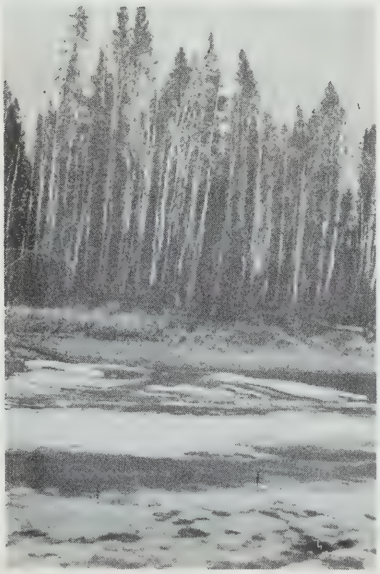


Photo 3.1.3
27 Apr 71
East abutment

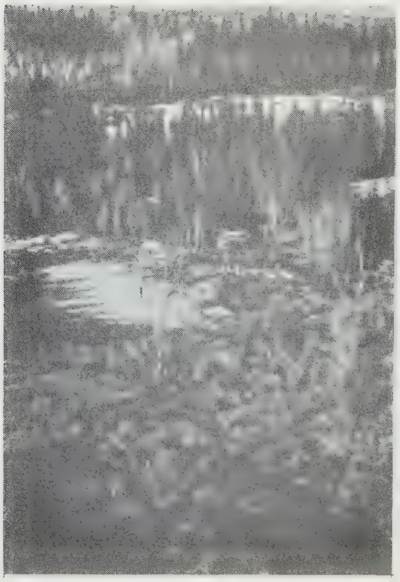


Photo 3.1.4
28 Apr 71
Looking SW across
marsh near E. abutment

Photo 3.2.1
28 Apr 71
East abutment

Photo 3.2.2
28 Apr 71
Looking Northeast
towards East abutment

Photo 3.2.3
A.M. 28 Apr 71
Looking Northeast

Photo 3.2.4
P.M. 28 Apr 71
Looking Southwest
Note change in ice
cf. Photo 3.2.3

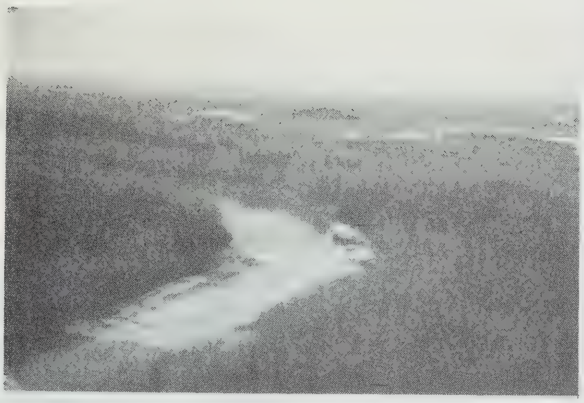


Photo 4.1.1
28 Apr 71
Looking West

Photo 4.1.2
29 Apr 71
Looking East

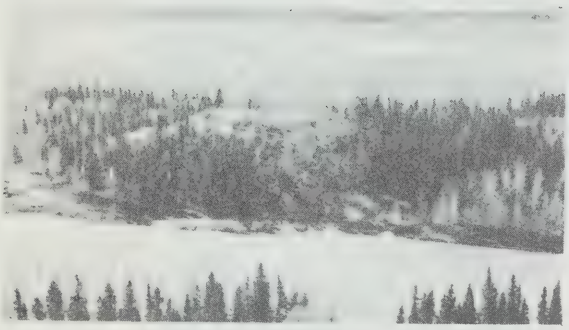


Photo 4.1.3
29 Apr 71
West abutment

Photo 4.1.4
29 Apr 71
East abutment

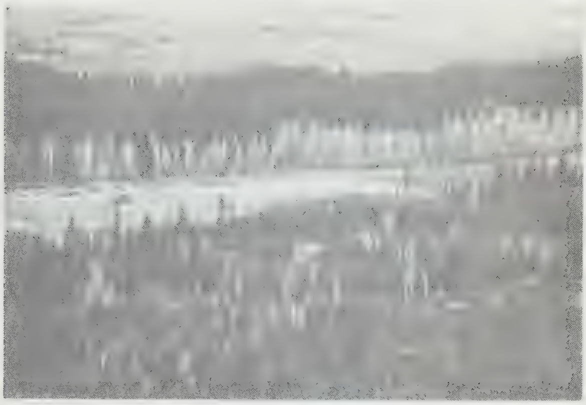


Photo 4.2.1
28 Apr 71
Looking North
Note winter road

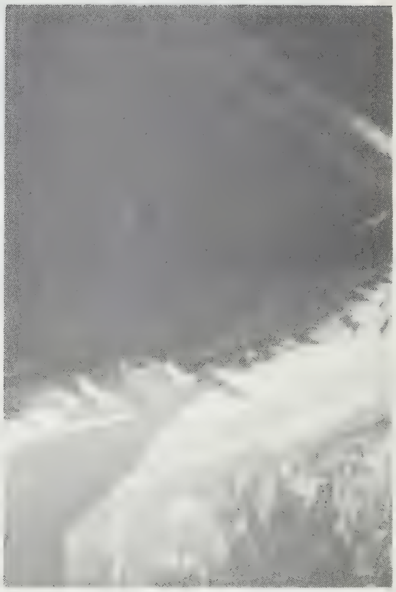


Photo 4.2.3
28 Apr 71
South abutment

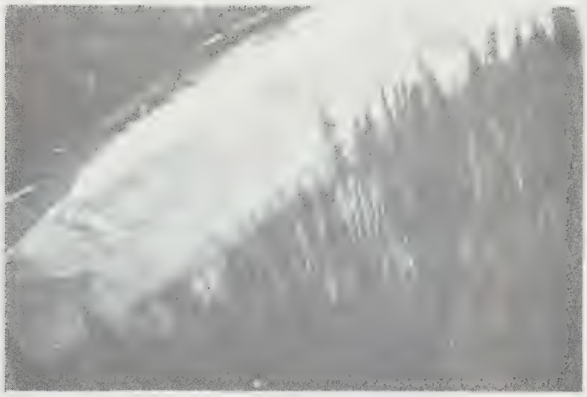


Photo 4.2.2
28 Apr 71
Looking South

Photo 4.2.4
29 Apr 71
Looking West along North abutment

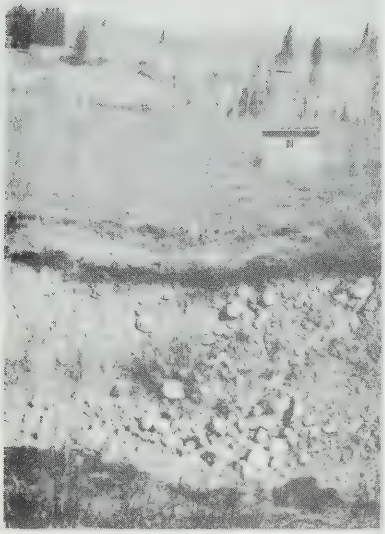


Photo 4.2.5
29 Apr 71
Small gravel pit
South of Location 4.2

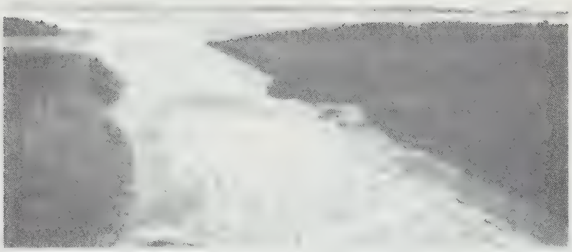


Photo 5.1.1
29 Apr 71
Looking Southeast

Photo 5.1.2
29 Apr 71
Looking North
along East abutment

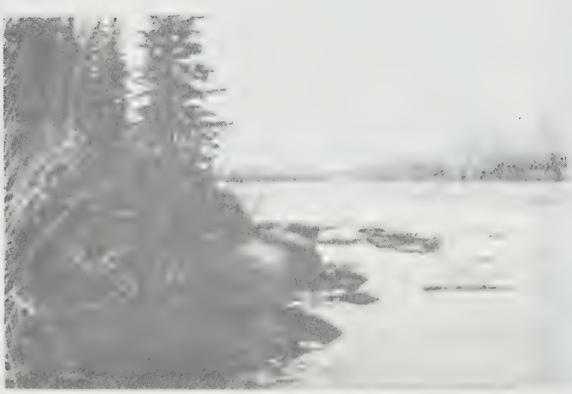


Photo 5.1.3
29 Apr 71
Looking North
along West abutment

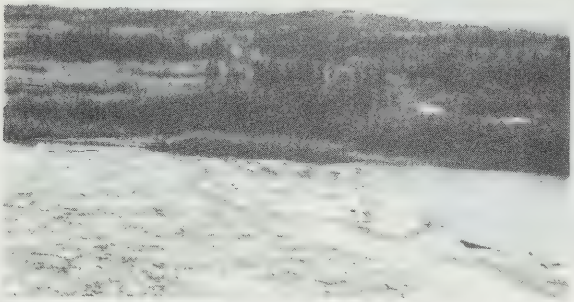


Photo 5.2.1
29 Apr.71
West abutment

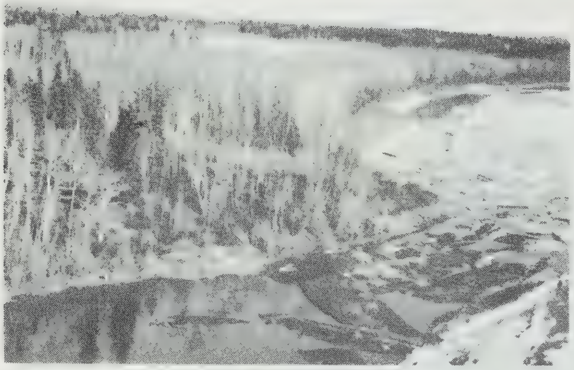


Photo 5.2.2
29 Apr 71
East abutment

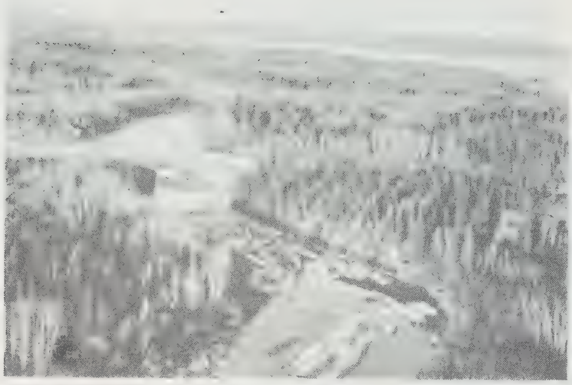


Photo 5.3.1
29 Apr 71
Looking East
Location 5.3 in foreground
Note vertical rock face
on South abutment

Photo 5.3.1
28 Apr 71
Looking West
Location 5.5 in foreground
Location 5.3 in left
middle distance

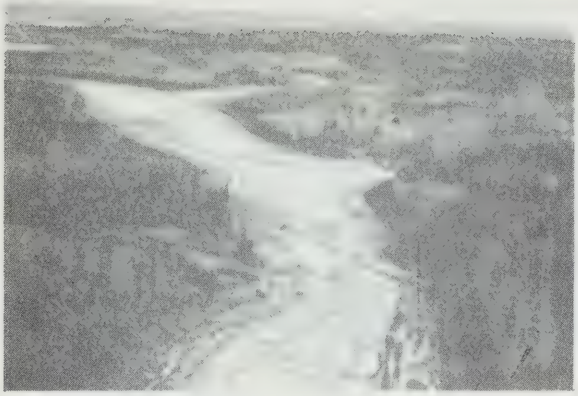


Photo 5.4.1
28 Apr 71
Looking North
5.6 above mid-photo

Photo 5.4.2
29 Apr 71
East abutment

Photo 5.4.3
30 Apr 71
West abutment

Photo 5.5.1
30 Apr 71
North abutment

Photo 5.5.2
28 Apr 71
Looking West
Location 5.5 in foreground

Photo 5.5.3
30 Apr 71
Looking West
North abutment

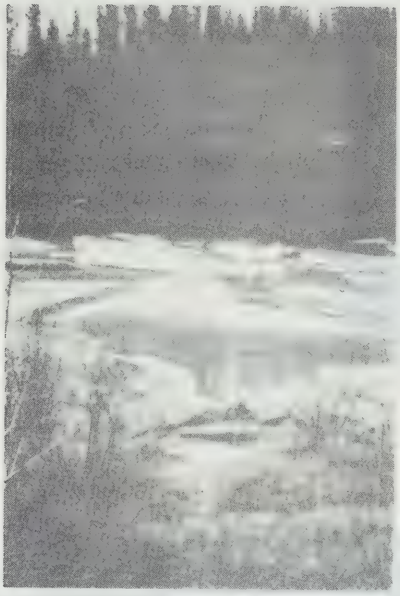


Photo 5.5.4
28 Apr 71
South abutment

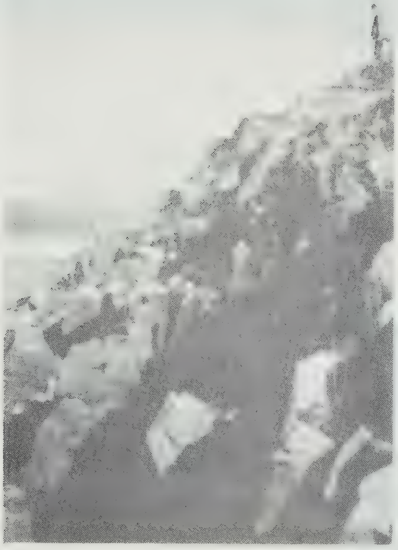


Photo 5.5.5
28 Apr 71
Near North abutment
This rock common to
East abutment of
Location 5.6

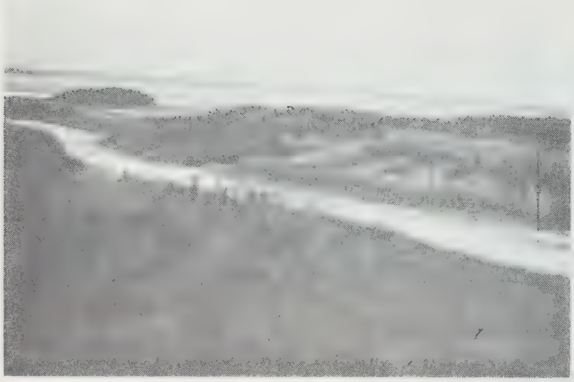


Photo 5.6.1
28 Apr 71
Looking South
Location 5.6 approximately
at centre of photo

Photo 5.7.1
27 Apr 71
Looking North
Location 5.7 in
foreground

Photo 5.7.2
27 Apr 71
Looking North along
East abutment

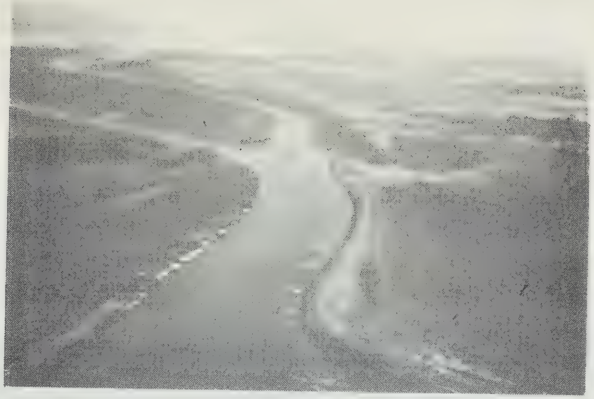


Photo 6.1.1
27 Apr 71
Looking Southwest

Photo 6.1.2
27 Apr 71
North abutment

Photo 6.1.3 & 6.1.4
27 Apr 71
Panorama looking Southwest

Photo 6.1.5
27 Apr 71
Outcrop 300' Northwest
of Location 6.1

Photo 7.1.1
27 Apr 71
Embarras River
Looking WNW
Headwaters of Mamawi
Creek on right

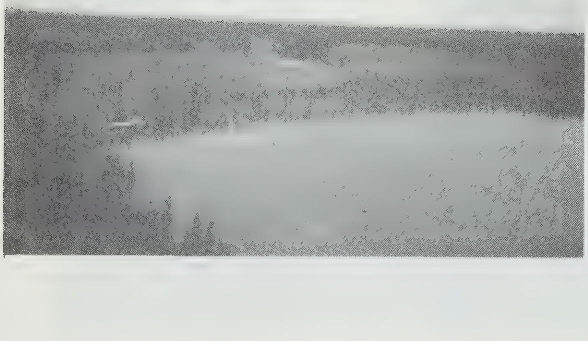


Photo 7.1.2
28 Apr 71
Athabasca River
Looking Northwest
at "cut-off"
(refer photo 7.1.4)

Photo 7.1.3
28 Apr 71
Athabasca River
Entrance to "new channel"
Looking North

Photo 7.1.4
27 Apr 71
Looking South
"Cut-off"
Athabasca River on left
Embarras River on right

Photo 8.1.1
27 Apr 71
Looking Southwest
Richardson Lake
in distance

Photo 8.1.2
27 Apr 71
Looking North across
outlet channel for
Richardson Lake

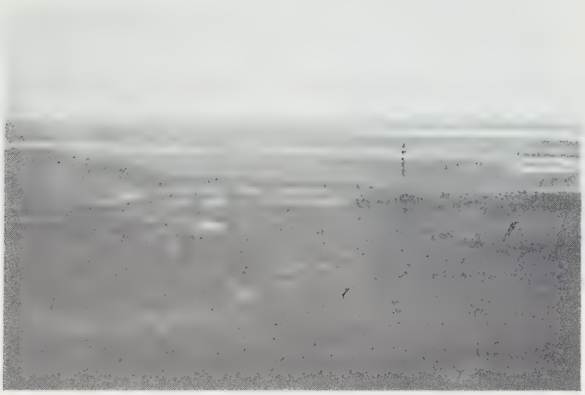


Photo 8.1.3
27 Apr 71
Looking Northwest
Dark pattern across
Richardson Lake
indicates flow fron
Maybelle River

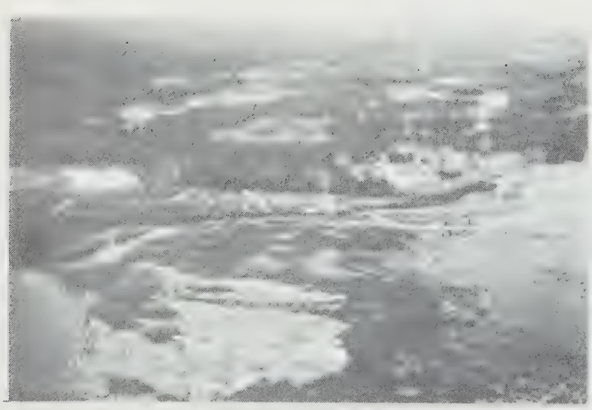


Photo 8.1.4
27 Apr 71
Looking South
West channel of
Maybelle River

SECTION Q

APPENDIX D

Preliminary Construction Possibilities

(Prepared by Peace-Athabasca Delta Project)

PEACE ATHABASCA DELTA PROJECT

PRELIMINARY CONSTRUCTION POSSIBILITIES

ALTERNATIVE "A"

- a control structure on the Slave River at Location 1
- purpose of control - to increase upstream water levels in the Slave and Peace Rivers, an average of approximately 6 feet
- type of construction could range from a simple rock fill weir or channel constriction, to a more elaborate gated concrete structure. Navigation and fish passage works will be considerations at this location.

ALTERNATIVE "B"

- control structures on

  (a) Riviere des Rochers at location 2
  (b) Revillon Coupe at location 3
  (c) Chenal des Quatre Fourches at location 4

- purpose of controls - to increase water levels in Lake Athabasca by an average of approximately 5 feet
- controls should also permit occasional flow in a southward direction from the Peace River to Lake Athabasca
- type of construction could range from simple rock fill weirs or channel constrictions, to more elaborate gated concrete structures. Navigation works will be a consideration at locations 2 and 4. Fish passage works will be a consideration at all three locations.

ALTERNATIVE "C"

- control structures on

  (a) Riviere des Rochers at location 5
  (b) Chenal des Quatre Fourches at location 4

- purpose of controls - to increase water levels in Lake Athabasca by an average of approximately 5 feet
- controls should also permit occasional flow in a southward direction from the Peace River to Lake Athabasca
- type of construction could range from simple rock fill weirs or channel constrictions to more elaborate gated conrete structures. Navigation and fish passage works will be considerations at both sites.

ALTERNATIVE "D"

- control structure on the outlet of Mamawi Lake at location 6, and diversion works on the Embarras River to add water to Mamawi Creek at location 7
- purpose of control - to control the amount of outflow from Mamawi Lake
- purpose of diversion - to augment the natural inflow to Mamawi Lake
- type of construction - lake outlet structure may be a simple fixed crest weir or gated structure. The diversion works will be a gated

structure and excavated canal. Both locations are anticipated to require careful consideration of soils in regard to erosion and channel regime. Fish passage works will be required at location 6, and facilities for passage of small boats will likely be desirable.

ALTERNATIVE "E"

- this is a special purpose undertaking to ensure the passage of fish between the Athabasca River and the Maybelle River via Richardson Lake at location 8.
- nature of works are as yet undetermined but could consist of a lake level control structure (fixed crest weir or gated), channel dredging or relocation, or piling works for channel control.

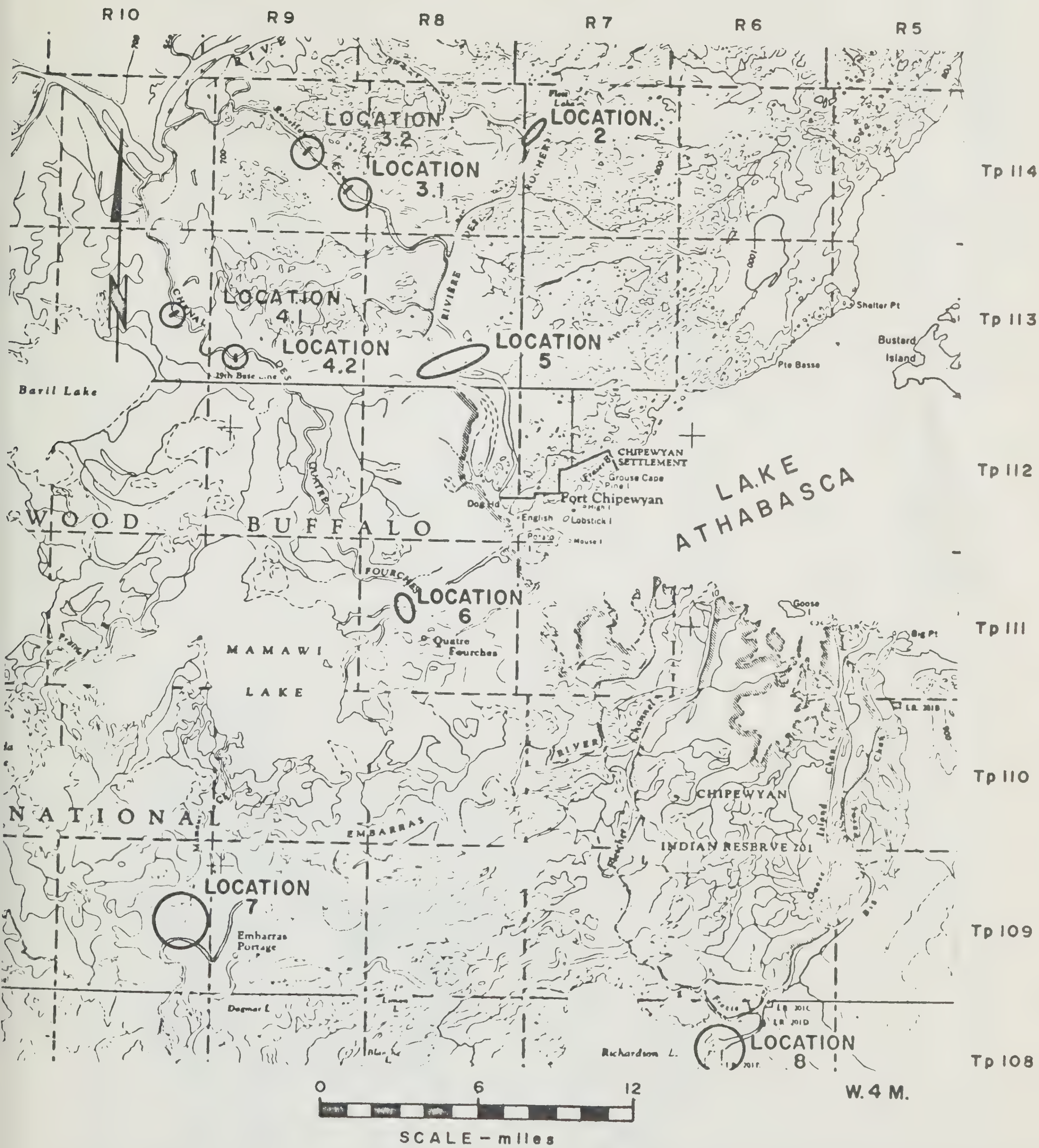
SECTION Q

APPENDIX E

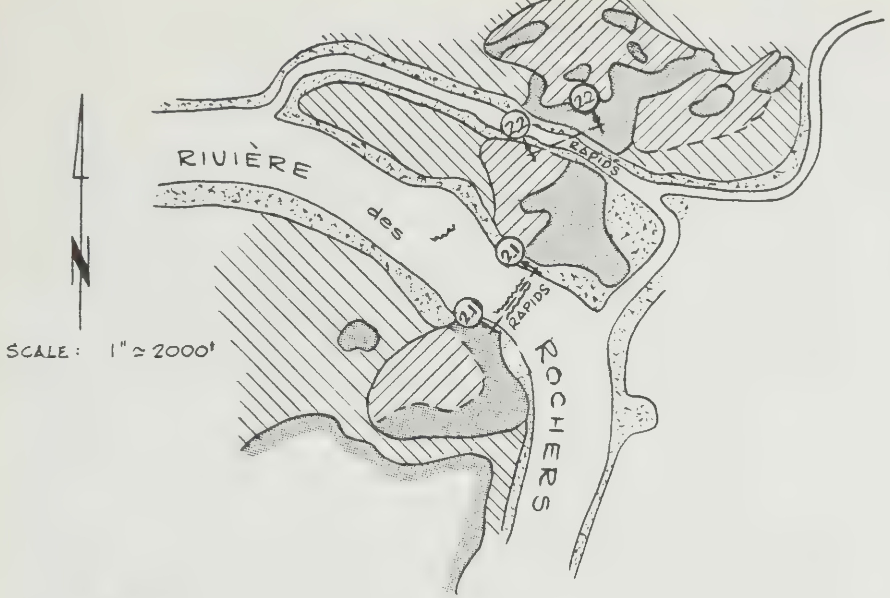
Drawings

DRAWING INDEX

Description	Drawing No.
Site Plan	E2143- 1
Location 2.1	E2143- 2
Location 2.2	E2143- 3
Location 3.1	E2143- 4
Location 3.2	E2143- 5
Location 4.1	E2143- 6
Location 4.2	E2143- 7
Locations 5.1-5.7	E2143- 8
Location 5.1	E2143- 9
Location 5.2	E2143-10
Location 5.3	E2143-11
Location 5.4	E2143-12
Location 5.5	E2143-13
Location 6.1	E2143-14
Location 7	E2143-15

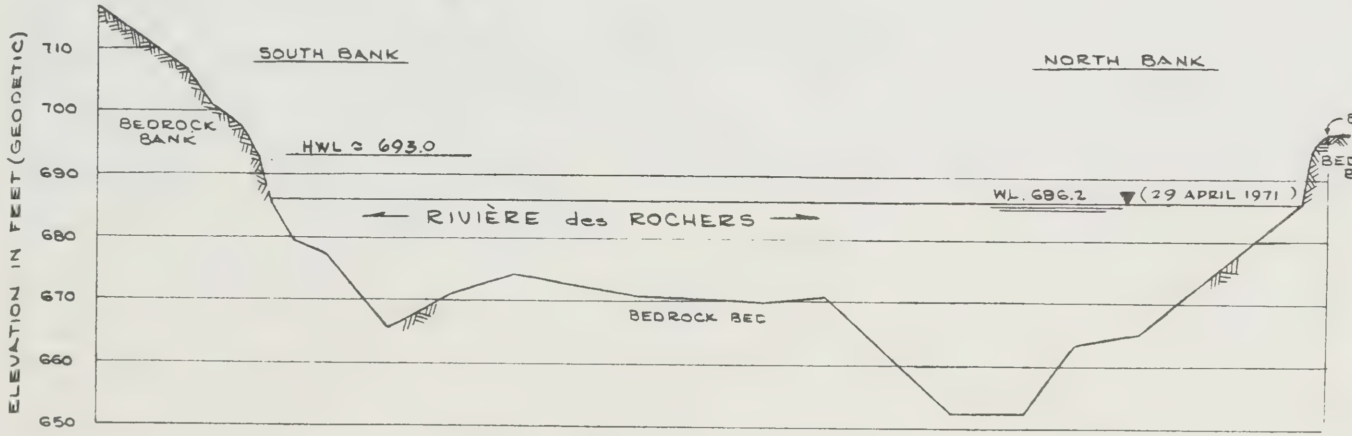


SCALE SHOWN DATE JUNE 1971	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE-ATHABASCA DELTA PROJECT
MADE ABV CHKD. APPD.		SITE PLAN
		No. E 2143 - 1 REV.



NOTES:

1. RIVER CROSS-SECTION DERIVED FROM DATA ON REF. 1. & R.M.H. FIELD SURVEY OF 27 - 29 APRIL 1971.
2. SEE DWG. E 2143 - 3 FOR SECTION 2-2.



SECTION 2.1 - 2.1
SCALE: VER. 1" = 20', HOR. 1" = 100'

LEGEND

- LEVEE: ALLUVIAL SANDY SILT
- DELTAIC SEDIMENTS: CLAYEY SILTS
- GLACIAL DRIFT: TILL, OUTWASH
- PRE-CAMBRIAN: GRANITE, GRANITE GNEISS

REVISIONS

REFERENCES
1. FIGURE 11, DATED SEPT. 1970, WATER RESOURCE DIVISION, ALTA., DEPT. OF AGRICULTURE.

SCALE SHOWN
DATE JUNE 1971
MADE
CHKD.
APPD.

RMH R. M. HARDY & ASSOCIATES LTD.
CONSULTING CIVIL ENGINEERS
EDMONTON ALBERTA

PEACE-ATHABASCA DELTA PROJECT

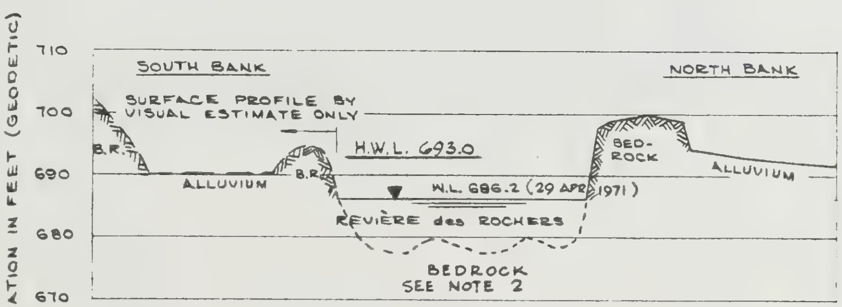
LOCATION 2-1

No. E 2143 - 2

REV.

NOTES

1. ELEVATIONS SHOWN ARE VERY APPROXIMATE, AS ELEVATION DETERMINED BY INFERRING WATER LEVEL AT LOCATION 2.2 EQUAL TO WATER LEVEL AT LOCATION 2.1 AT TIME OF SURVEY, 29 APRIL 1971.
2. BOTTOM OF CHANNEL IS BEDROCK, AS INDICATED BY RAPIDS IN AIR PHOTOS. DEPTH OF CHANNEL SHOWN IS ESTIMATED ONLY; POSSIBLE ERROR IS ± 5'.

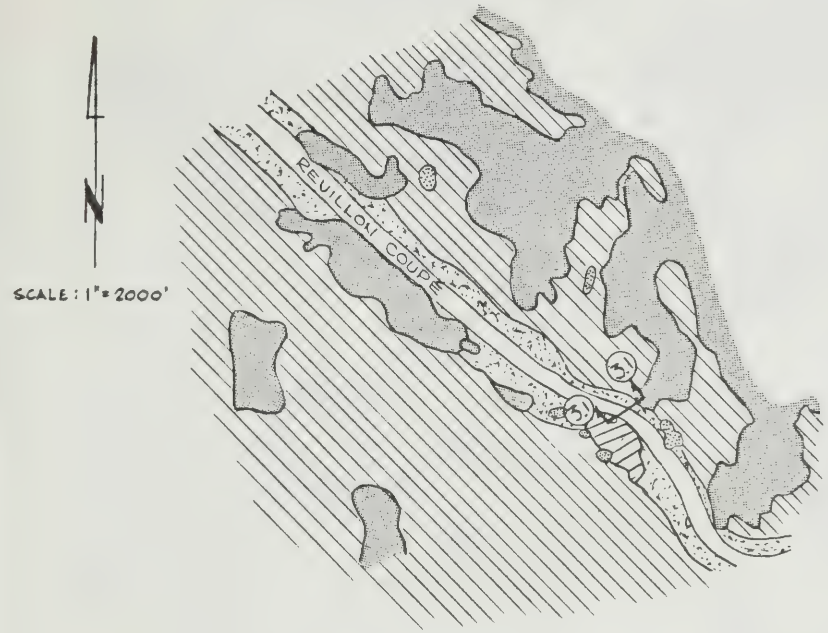


SECTION 2.2-2.2
SCALE: VER. 1" = 20'
HOR. 1" = 100'

REVISIONS	REFERENCES			
	1. R.M.H. DWG. E 2143-2.	SCALE SHOWN DATE JUNE 1971 MADE ABV CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 2·2 No. E 2143 - 3 REV.

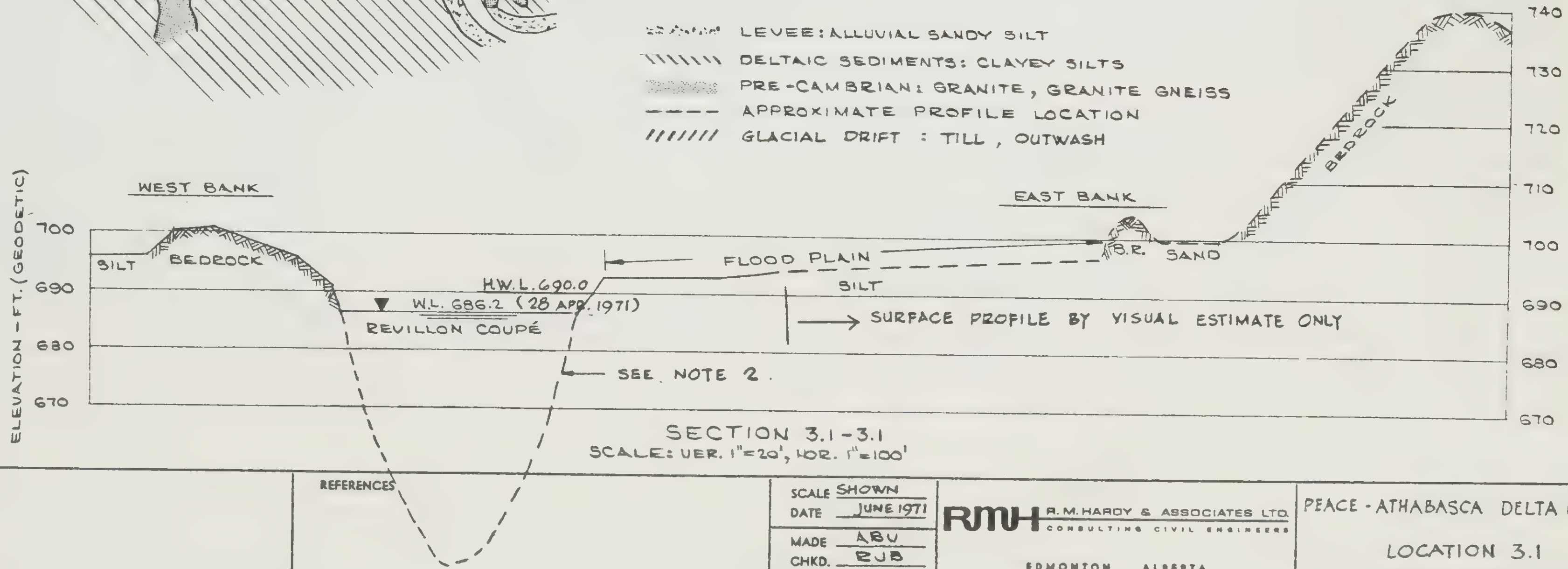
NOTES:

1. ELEVATIONS SHOWN ARE VERY APPROXIMATE AS ELEVATION DETERMINED BY ASSUMING WATER LEVEL AT LOCATION 3.1 ≈ WATER LEVEL AT LOCATION 2.1 AT TIME OF R.M.H. SURVEY 28 - 29 APRIL 1971.
2. RIVER BOTTOM INFERRED FROM PEACE-ATHABASCA DELTA PROJECT SECTION # 38, SURVEYED 10 JULY 1970, AND RIVER THALWEG PROFILE, JULY 1970.



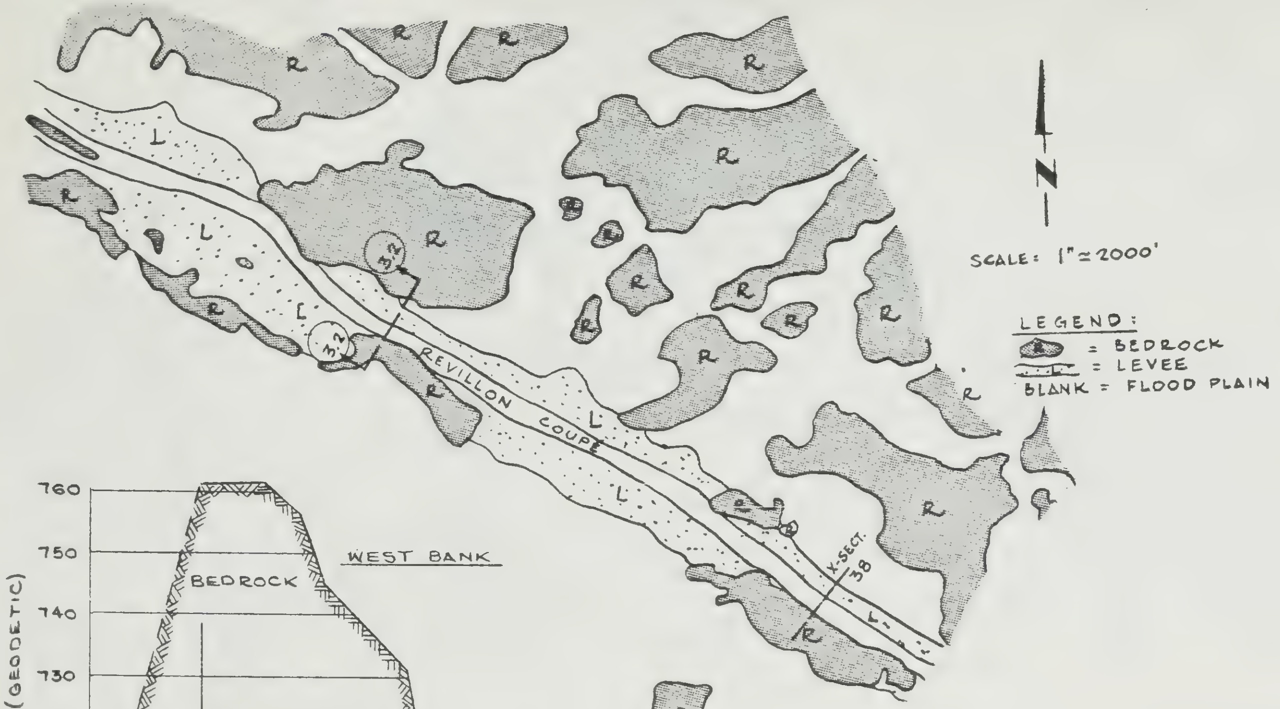
LEGEND

- LEVEE: ALLUVIAL SANDY SILT
- DELTAIC SEDIMENTS: CLAYEY SILTS
- PRE-CAMBRIAN: GRANITE, GRANITE GNEISS
- APPROXIMATE PROFILE LOCATION
- GLACIAL DRIFT: TILL, OUTWASH



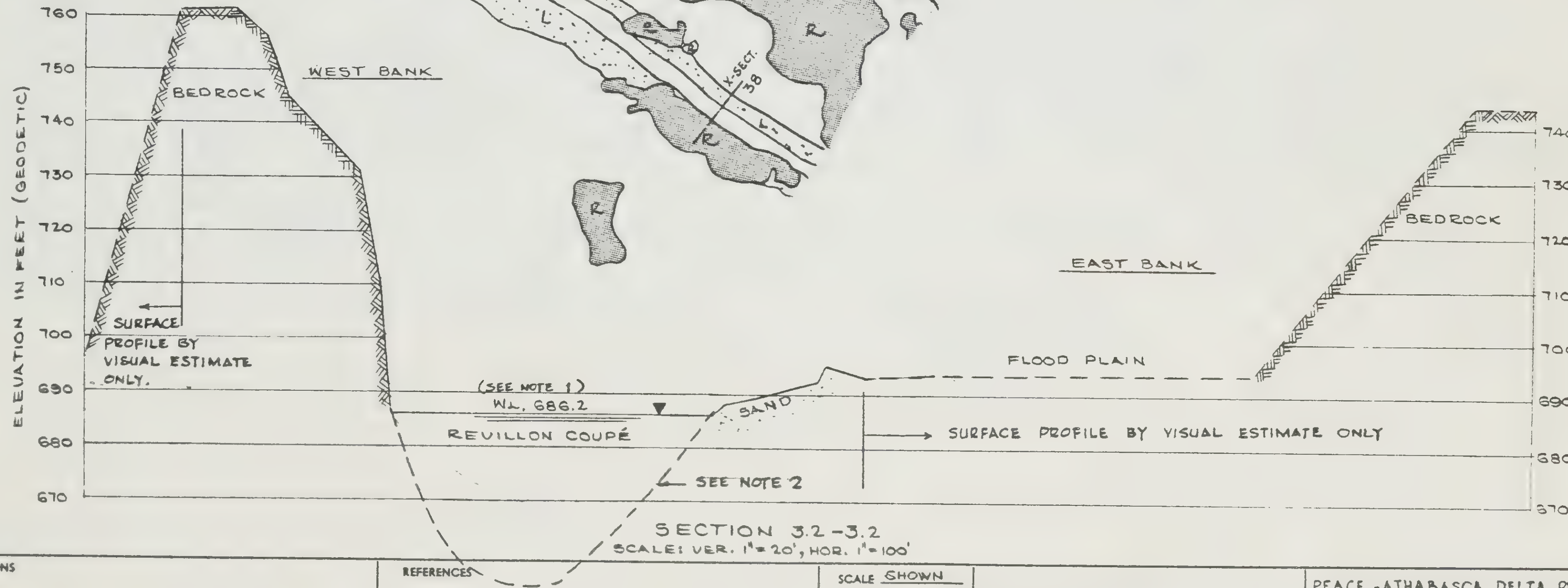
SECTION 3.1 - 3.1
SCALE: VER. 1" = 20', HOR. 1" = 100'

REVISIONS	REFERENCES	SCALE SHOWN DATE JUNE 1971 MADE ABU CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 3.1 No. E 2143 - 4 REV.



NOTES:

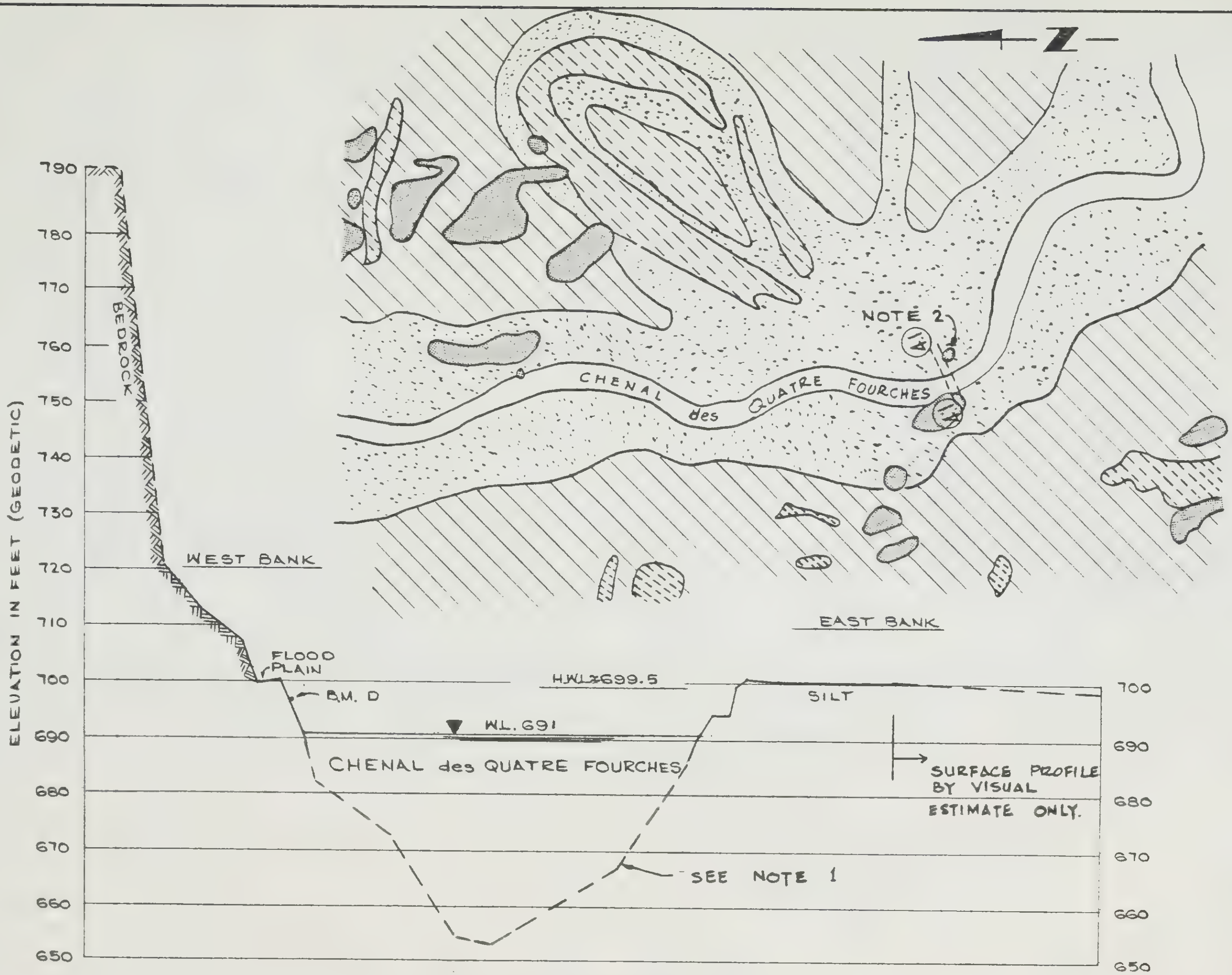
1. ELEVATIONS SHOWN ARE VERY APPROXIMATE AS THEY HAVE BEEN DETERMINED BY ASSUMING W.L. AT LOCATION 3.2 ≃ W.L. AT LOCATION 2.1 AT TIME OF R.M.H. SURVEY 28 - 29 APRIL 1971.
2. RIVER BOTTOM INFERRED FROM PEACE - ATHABASCA DELTA PROJECT SECTION # 38, SURVEYED 10 JUNE 1970. AND RIVER THALWEG PROFILE, JULY 1970.



SECTION 3.2 - 3.2

SCALE: VER. 1" = 20', HOR. 1" = 100'

REVISIONS	REFERENCES			
	1. 15 OCT. 70 AIR PHOTOS LINE 20 MAP SHEET 74 - L - 14.	SCALE SHOWN DATE JUNE 1971 MADE ABU, CP CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 3.2 No. E 2143 - 5 REV.



SECTION 4.1 – 4.1
SCALE: VER. 1" = 20', HOR. 1" = 100'

NOTES:

1. RIVER BOTTOM FROM PEACE - ATHABASCA DELTA PROJECT X - SECTION #13, 10 JULY 1970.
2. EXISTENCE OF BEDROCK ON EAST BANK IS DOUBTFULL. OUTCROP SHOWN INFERRED FROM AIR PHOTOS ONLY.

SCALE 1" = 2000'

LEGEND:

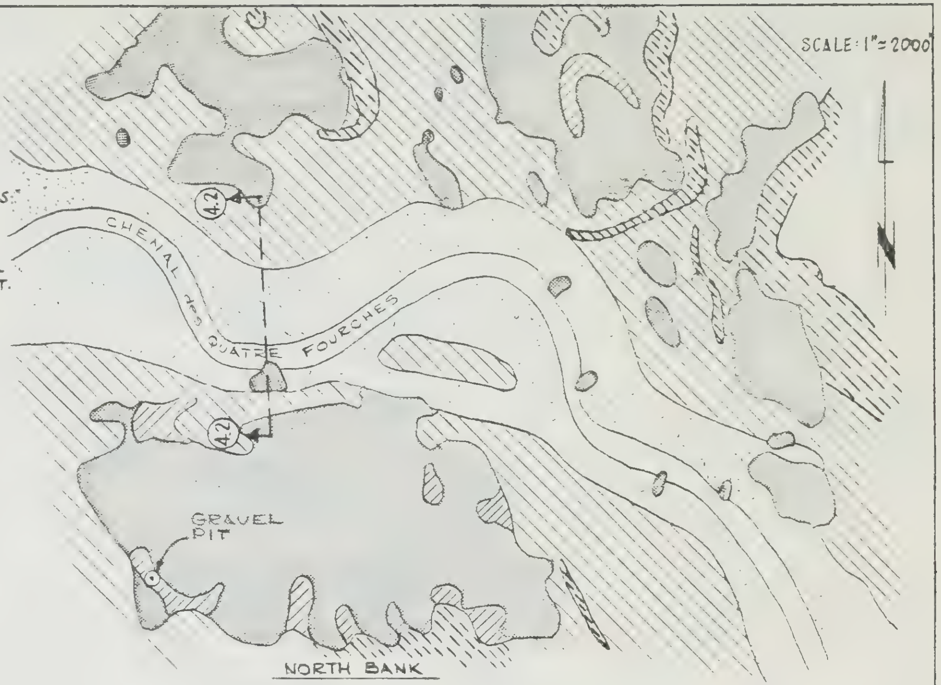
- LEVEE: SANDY SILT.
- DELTAIC SEDIMENT: CLAYEY SILT.
- DELTAIC MARSH WITH STANDING WATER.
- PRE-CAMBRIAN: GRANITE, GRANITE GNEISS.

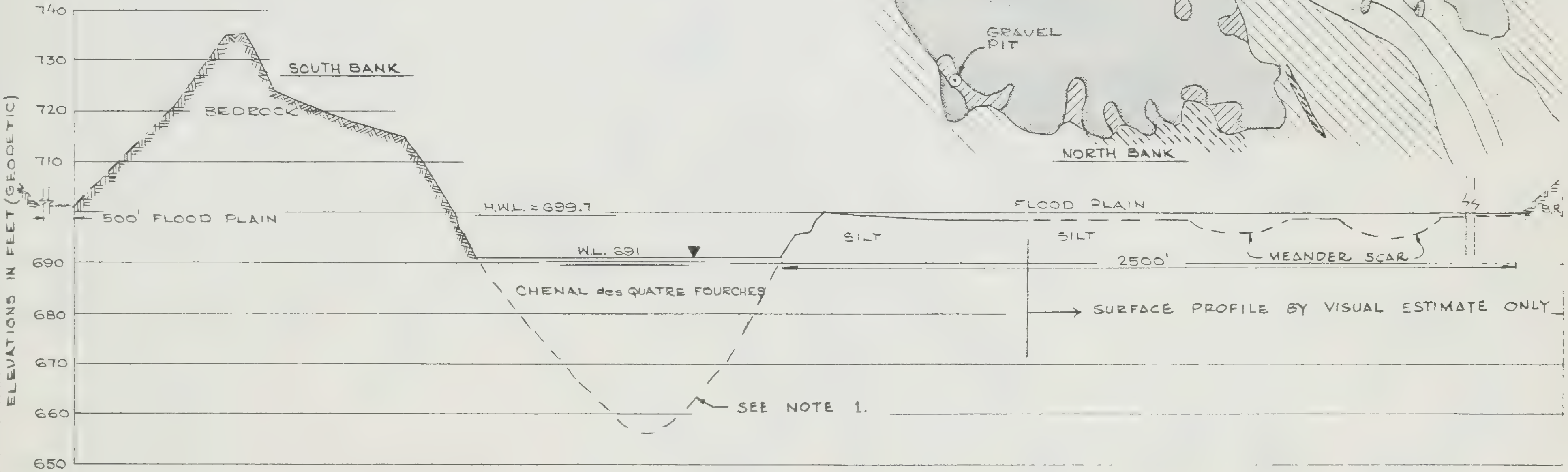
REVISIONS	REFERENCES	SCALE SHOWN DATE JUNE 1971 MADE ABU,CP CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 4.1 No. E 2143 - 6 REV.

NOTES:
1. RIVER BOTTOM INFERRED FROM PEACE-ATHABASCA DELTA PROJECT, X-SECTIONS #11 & #12 (10 JULY 70)
2. ELEVATIONS DERIVED ON ASSUMPTION THAT W.L. AT LOCATION 4.2 ≃ W.L. AT LOCATION 4.1 ON DATE OF SURVEY (28 APR. 71)

LEGEND:

- LEVEE: SANDY SILT.
- DELTAIC SEDIMENTS: CLAYEY SILT.
- OUTWASH GRAVEL OR TILL: POTENTIAL AGGREGATE DEPOSIT.
- DELTAIC MARSH WITH STANDING WATER.
- PRE-CAMBRIAN: GRANITE, GRANITE GNEISS.





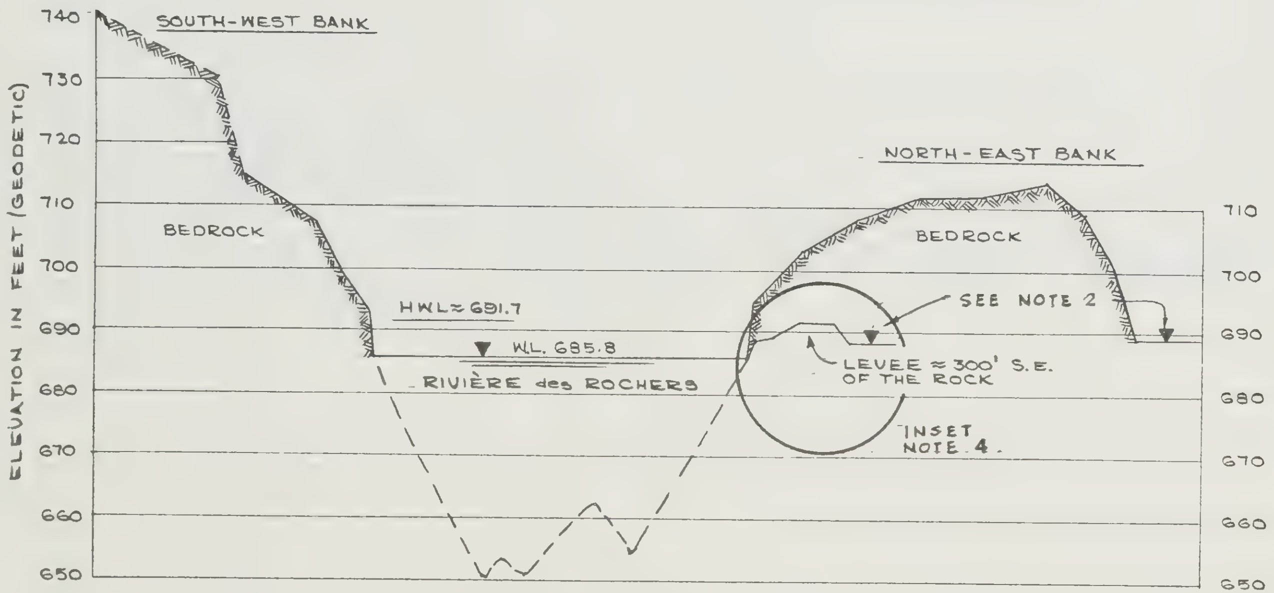
SECTION 4.2 - 4.2
SCALE: VER. 1"=20', HOR. 1"=100'

REVISIONS	REFERENCES	SCALE SHOWN DATE JUNE 1971 MADE ABU CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE-ATHABASCA DELTA PROJECT LOCATION 4.2 No. E 2143 - 7 REV.

LEGEND

- LEVEE SANDY SILT
- DELTAIC SEDIMENTS CLAYEY SILTS
- OUTWASH GRAVEL OR TILL : POTENTIAL AGGREGATE DEPOSIT
- DELTAIC MARSHES WITH STANDING WATER
- DELTAIC SEDIMENTS, NEW; CLAYEY SILT
- PRE-CAMBRIAN : GRANITE, GRANITE GNEISS

SCALE 1" ≏ 2000' DATE MAY 71 MADE CCP CHKD. APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATIONS 5.1 - 5.7 No. E 2143 - 8 REV.



SECTION 5.1 - 5.1
SCALE: VER. 1" = 20', HOR. 1" = 100'

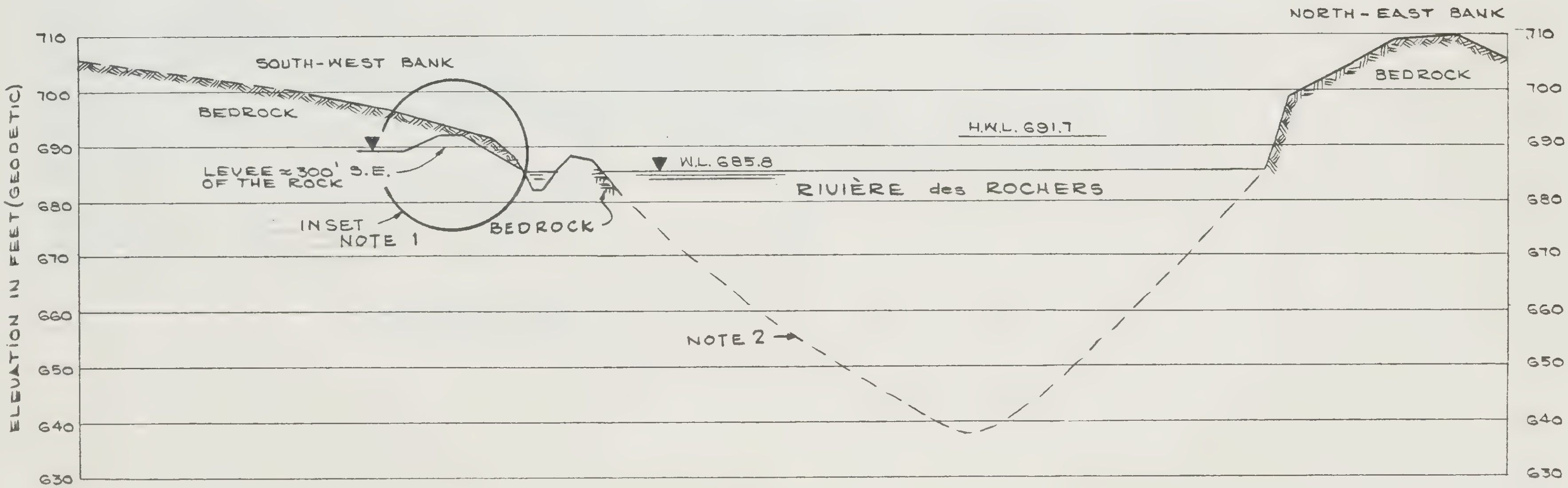
NOTES :

1. ELEVATIONS SHOWN OBTAINED BY CORRELATING W.L.'s WITH B.M. WSC-3.
2. ADDITIONAL W.L.'s SHOWN ARE FOR MARSHES IMPOUNDED BY LEVEES.
3. SEE DWG. E2143-8 FOR PLAN VIEW OF SITE.
4. INSET SHOWS LEVEE PROFILE AS SURVEYED SOUTH OF ROCK OUTCROP.
5. RIVER BOTTOM PROFILE FROM PEACE - ATHABASCA DELTA PROJECT X-SECTION #24, 12 JULY 1971, AND SURFACE PROFILE FROM R.M.H. SURVEY 29 APRIL 1971.

REVISIONS	REFERENCES			
	1. R.M.H. DWG. E 2143 - 8.	SCALE SHOWN DATE JUNE 1971 MADE ABU CHKD. RJB APPD.	RMH R.M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 5.1 No. E 2143 - 9 REV.

NOTES:

1. INSET SHOWS PROFILE OF LEVEE AT ≃ 300' SOUTH OF ROCK OUTCROP.
2. RIVER BOTTOM INFERRED FROM PEACE - ATHABASCA DELTA PROJECT X - SECTION # 23.
3. ELEVATIONS OBTAINED BY REFERRING W.L.'s TO B.M. WSC - 3.

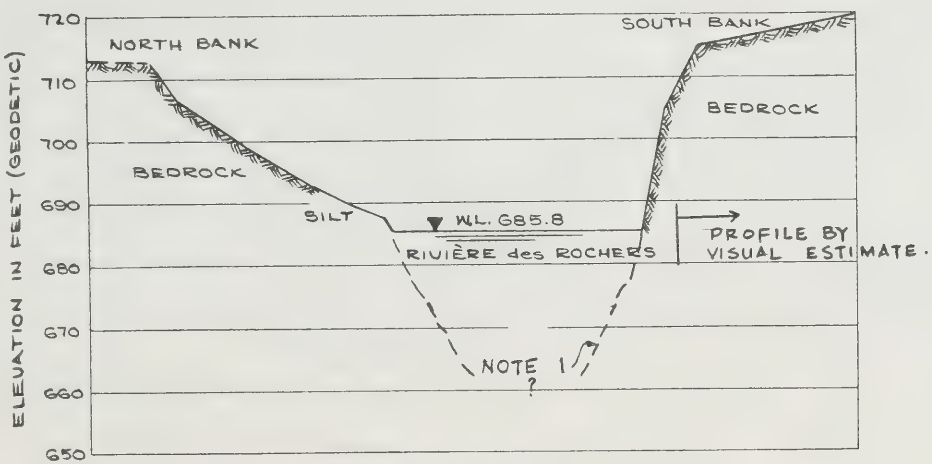


SECTION 5.2 - 5.2
SCALE: VER. 1" = 20', HOR. 1" = 100'

REVISIONS	REFERENCES			
	1. R.M.H. DWG. E 2143-8.	SCALE SHOWN DATE JUNE 1971 MADE ABU CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 5.2 No. E 2143 - 10 REV.

NOTES:

1. NO DATA AVAILABLE FOR RIVER BOTTOM.
2. ELEVATIONS OBTAINED BY REFERENCING W.L.'s TO B.M. WSC-3.

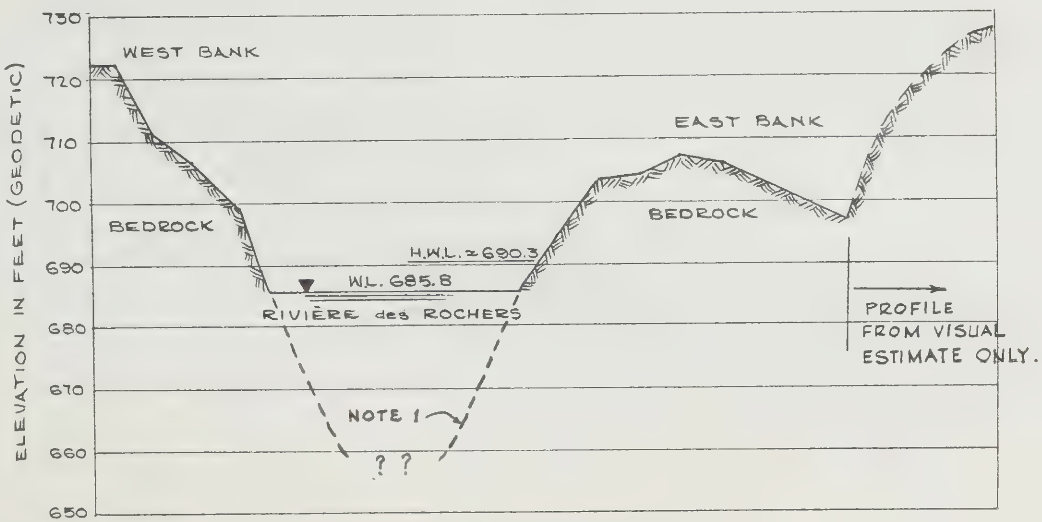


SECTION 5.3-5.3
SCALE: VER. 1"=20', HOR. 1"=100'

REVISIONS	REFERENCES			
	1. R.M.H. DWG. E2143 - 8.	SCALE SHOWN DATE JUNE 1971 MADE ABV CHKD. RJB APPD.	RMH R.M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE-ATHABASCA DELTA PROJECT LOCATION 5.3 No. E 2143 - 11 REV.

NOTES:

1. NO DATA AVAILABLE FOR RIVER BOTTOM.
2. ELEVATION OBTAINED BY REFERENCING W.L.'S TO B.M. WSC-3.

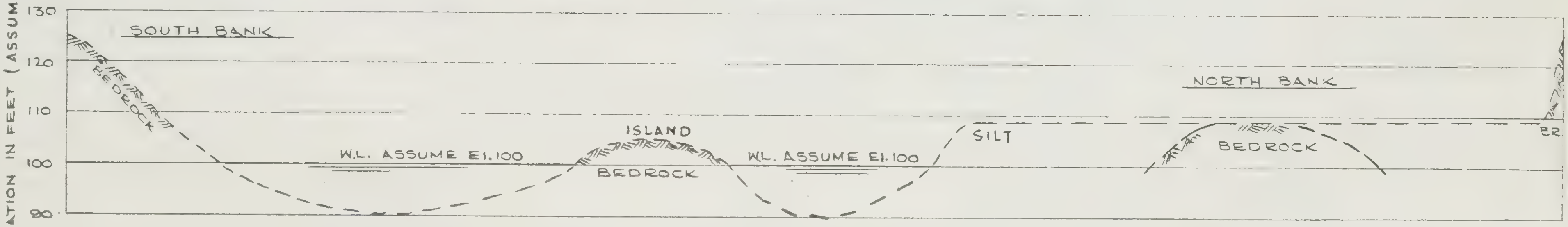


SECTION 5.4-5.4
SCALE: VER. 1" = 20', HOR. 1" = 100'

REVISIONS	REFERENCES			
	1. R.M.H. DWG. E 2143-8	SCALE SHOWN DATE JUNE, 1971 MADE ABU CHKD. RJB APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE-ATHABASCA DELTA PROJECT LOCATION 5.4 No. E 2143 - 12 REV.

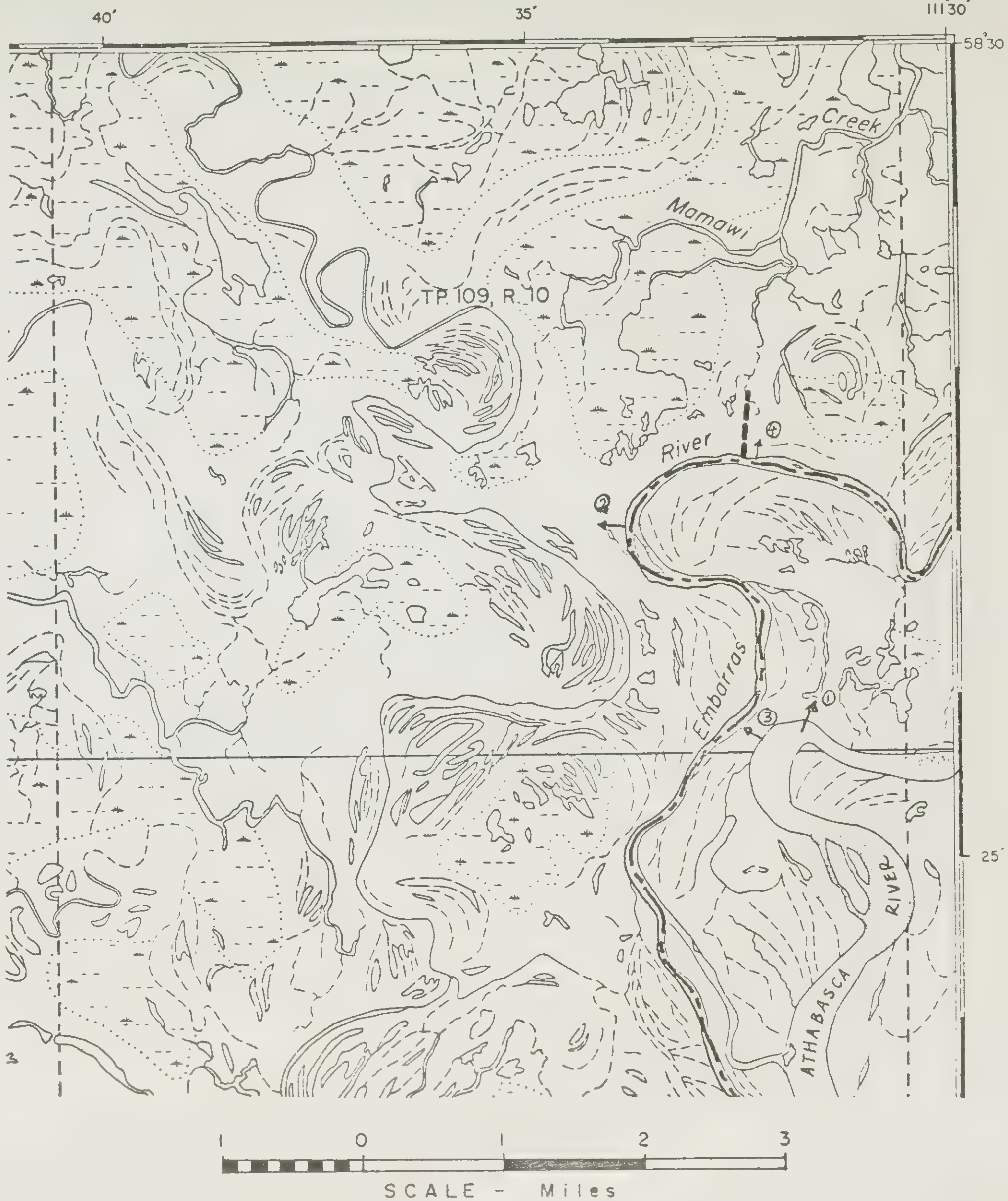
NOTES:

1. W.L. ASSUMED = 100' ON R.M.H. SURVEY OF 27 APRIL 1971.
2. RIVER CHANNEL BOTTOM: INFERRED FROM PEACE-ATHABASCA DELTA PROJECT, X-SECTION #5 (11 JULY '70)
3. SURFACE PROFILE FROM VISUAL ESTIMATE ONLY.



SECTION 6.1-6.1
SCALE: VER. 1"=20', HOR. 1"=100'

REVISIONS	REFERENCES	SCALE SHOWN DATE JUNE '71. MADE ABV CHKD. RJB APPD.	RMH R.M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE-ATHABASCA DELTA PROJECT LOCATION 6.1 No. E 2143-14 REV.



LEGEND:

← OVERFLOW AT FLOOD STAGE, 27 APRIL 1971.

PROPOSED CANAL

REFERENCES	SCALE: SHOWN DATE: JUNE, 1971 MADE: CCP CHKD. APPD.	RMH R. M. HARDY & ASSOCIATES LTD. CONSULTING CIVIL ENGINEERS EDMONTON ALBERTA	PEACE - ATHABASCA DELTA PROJECT LOCATION 7 No. E 2143 - 15 REV.

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